

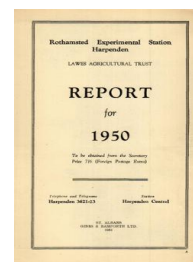
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Statistics Department

F. Yates

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STATISTICS DEPARTMENT

By F. YATES

During 1950 the work of the department was continued along the lines which have been outlined in previous reports. Work on the design and interpretation of experiments, particularly for the National Agricultural Advisory Service, has continued to grow.

On the survey side, work on surveys of the operational research type has again been at a high level. The Survey of Marginal Land was completed, and the data provided proved of assistance to the Committee set up by the Ministry of Agriculture to advise the Government on future policy with regard to such land. It will be recalled that the object of the survey was to investigate how far marginal land of the type not included in the Hill Farming Act and not producing cash crops such as dairy products was likely to repay a scheme of rehabilitation. Government assistance has since been provided for such land on the lines recommended by the Committee. The third and final year's field work of the Survey of Maincrop Potatoes has been completed, and the results are now being analyzed. A further Survey of Fertilizer Practice was carried out in nine districts scattered over the country. Two further districts are at the moment awaiting survey. The object of this survey, which will be repeated in 1951 and probably in 1952, is to see what changes in fertilizer practice are taking place as a result of the considerable alterations in price consequent on the changes in subsidies. The preliminary work on the Survey of Opencast Coal is completed and detailed work is about to commence. Local surveys on garden chafer beetles and brassica crops were also carried out in conjunction with the National Agricultural Advisory Service.

The first full year's working of the Hollerith equipment has proved its value. Modifications, basically designed by members of the department, increasing the scope and versatility of the tabulator, have now been installed.

During the last few years the need for additional accommodation has become increasingly pressing. At the beginning of 1950 it was decided that the best course would be to construct a new building to house the entire department, leaving Rivers Lodge free for other purposes. Detailed plans for this building have now been completed.

DESIGN AND ANALYSIS OF EXPERIMENTS

The design and analysis of field and laboratory experiments for Rothamsted and other research stations has continued on the usual lines. Co-operation with the National Agricultural Advisory Service in the field of experimental design and analysis has again made very good progress. We are continuing to be consulted by all provinces, and Dr. Boyd or some other member of the department usually attends meetings of the Provincial Experiments Committees in most provinces.

The Crop Experiments Sub-Committee and the Animal Experiments Sub-Committee of the Ministry of Agriculture's Experimental

Husbandry Committee have been very active during the year considering proposals and making plans for experiments at the Experimental Husbandry Farms. Dr. Yates is a member of both these Committees and recently Mr. Rees has been assigned the task of assisting in the statistical work on the animal side. He prepared a note summarizing the results of experiments on the feeding of sugar beet and fodder beet to pigs (49). It is intended that an expanded version of this note shall be published. This headquarters organization is now playing an increased part in the planning of co-operative experiments carried out by the National Agricultural Advisory Service. Dr. Yates has also assisted in some of the preliminary work concerned with the planning of experiments for the Experimental Horticulture Farms. In this he was assisted by Mr. Nelder, statistician to the Vegetable Research Station who, as mentioned in the previous report, has been housed in the department during the past year pending the completion of buildings at Wellesbourne.

A good deal of attention has been paid to the problem of estimating the yields of the herbage plots on the Ley-Arable experiment at Rothamsted by means of grazing sheep, and by cutting samples of grass. The actual field work in connection with the cutting of grass samples has been undertaken by members of the department. The results as far as the sheep are concerned have been disappointing, but it is hoped that changes in technique may effect an improvement.

Various problems in the theory of the design of experiments have been investigated in the course of the year. Dr. Grundy has prepared a paper on a general technique for the analysis of experiments with incorrectly treated plots (39). Previous to this paper each case in which plots were incorrectly treated, e.g. by transposing two treatments, had to be analyzed by least squares methods, except for a limited range of problems in randomized blocks. The present research provides a method which is widely applicable and can be carried out without any complicated algebra. Mr. Healy wrote a paper on the design of probit assays (40). This dealt with the commonly used 2×3 point design and gave graphs from which the number of test objects needed to attain a desired degree of accuracy could be roughly assessed in advance. He has also described the methods used in a special case of analysis of non-orthogonal experimental data which should be of considerable value as an illustration of the way in which the best use may be made of such data (41). He collaborated with Mr. Leach of the Veterinary Laboratory, Weybridge, in clearing up some confusion which had arisen in correspondence in *Nature* on the statistical analysis of the results of successive tests on the same organism (45).

Mr. Patterson has continued his work on long-term and cyclical experiments. He also collaborated with Mr. Dyke in the development of a method of analyzing non-orthogonal factorial arrangements in which the data are in the form of proportions. In such cases it is necessary to scale the data, since the postulate of additive effects of the various factors, which forms the basis of the ordinary analysis of variance procedure, cannot operate over the limited

range, from 0 to 1, of the proportions. The scaling transformation proposed for the proportion $p (= 1 - q)$ is

$$z = \frac{1}{2} \log_e p/q$$

A paper is in the course of preparation.

SAMPLING METHODS

A considerable amount of advice on the design of sample surveys of various kinds has been given to people working in agriculture and other fields, both here and abroad. Dr. Yates attended the 4th Session of the United Nations Sub-Commission on Statistical Sampling where he contributed a paper to a discussion on operational research (50).

SURVEY OF FERTILIZER PRACTICE

In view of changes which might be expected in fertilizer practice arising from the reduction and modification of subsidies this survey was carried out in nine districts scattered over the country during the year. A further two districts are awaiting survey. It is proposed that comparable districts should be surveyed during the next year or two so as to enable trends to be examined.

The primary objects of the survey are to determine the amounts of fertilizer used on the different crops in different districts of the country. In addition, information has been obtained on methods of fertilizer distribution and times of application, and wherever possible soil analyses have been carried out for a sub-sample of the surveyed fields. Supplementary information has been sought on the availability of fertilizers and on the opinions of farmers regarding the use of nitrogen for cereals and for grassland.

The field work has been carried out, as in previous years, by the National Agricultural Advisory Service through the provincial Advisory Chemists. As a Hollerith installation is now available in the department and as the number of districts surveyed during the year was larger than usual, the returns have been handled on punched cards. This has made it practicable to examine the data in numerous ways and, in particular, various systems of weighting are being examined for bias and the sampling errors of estimates are being investigated.

A brief summary of this year's results is given in a separate article in this report.

During the year reports have been prepared on earlier surveys in two districts (48a, 48b).

SURVEY OF MAINCROP POTATOES

The Survey of Maincrop Potatoes which was begun in 1948, has now completed its third and final year, and the results are at present being analyzed. It will be recalled that the survey had been carried out in co-operation with officers of the National Agricultural Advisory Service. The survey is intended to furnish comprehensive and precise information on the agricultural practices followed in growing maincrop potatoes. It is also designed to test the possibility of estimating the yield of the crop by digging and weighing

short lengths of row shortly before harvest, and also to test the possibility of forecasting the yield of the crop by digging up similar lengths of row at an earlier date. The interim report on the first two years' results is being published in the National Agricultural Advisory Service Quarterly Review (38). It is hoped that a further report on the whole survey will be issued during 1951.

Although the average yields were decidedly lower in 1949 the comparison between the yields obtained from the survey with those of the corresponding Ministry estimates gave very similar results in 1949 to those obtained in 1948. These comparisons are shown in the following table.

TABLE 1. *Comparison of net sample yields with estimates of the Ministry of Agriculture (tons/acre)*

	1948	1949
Ministry of Agriculture estimates (excluding first earlies—sampled counties only)	8.1	7.2
Deduction for seed and chats (estimated from the survey results)	0.3	0.4
	7.8	6.8
Net yield of ware (1½ in.) from samples	9.5	8.5
Difference	1.7	1.7

The results for 1948 differ from those already given for that year in the 1949 Rothamsted Report mainly because a deduction has now been made from the Ministry's estimates for seed and chats. It has now been verified that the Ministry's estimates are intended to include seed and chats. On the other hand, it should be borne in mind that the Ministry's estimates include second earlies, whereas the survey results refer to maincrop potatoes only. Also the sample yields do not take into account losses in the clamp—nominally this is also true of the Ministry estimates, but some unconscious allowance may be made for such losses.

It will be seen that the discrepancy between the sample yields and the Ministry's estimates is identical in both years. The returns for the separate districts indicate clearly that the discrepancy arises mainly through under-estimation of the yields of the high-yielding counties. This is shown in the attached figure.

In both years the estimates obtained from the samples were compared with the farmers' weighed yields in cases where these were available, mainly cases in which the potatoes were sold directly off the field. This comparison is shown in the following table which also shows the allowances which had to be made for the amount of ware left in the ground, and for over-statement of the acreages actually grown. These allowances were determined by supplementary sampling. In both years the agreement between the correct sample yields and the farmers' weighed yields is very satisfactory. The large quantity of potatoes left in the ground, about three-quarters of a ton of ware potatoes per acre, is also noteworthy.

TABLE 2.* *Comparison of farmers' weighed yields and sample yields (tons/acre)*

	1948	1949
Number of fields	136	72
Mean yield (gross) of ware from samples ($1\frac{1}{4}$ in. riddle)	11.3	8.9
Less : ware left in ground ..	0.8	0.7
deduction for acreage correction	0.4	0.4
deduction for change of riddle to $1\frac{1}{2}$ in.	0.3	—
Total deduction	1.5	1.1
Mean yield (net) from sample ..	9.8	7.8
Mean of farmers' weighed yields ..	9.5	7.8
Mean excess of sample over weighed yields	+0.3	0.0

* Occasional small discrepancies between the present tables and those issued in earlier reports are due to rescruity of the data or minor changes in methods of calculating.

Some preliminary comments on the agricultural practices in the growing of potatoes will be found in the report referred to above. Fuller comment must await the complete analysis of the three years' results.

OTHER SURVEYS

As mentioned in the introduction the Survey of Marginal Land in England and Wales was completed in the early part of 1950. Sanction has now been obtained to prepare a report for publication.

A survey was undertaken jointly with the National Agricultural Advisory Service South-Western Province of an area of downland in Dorset which was heavily infested with the garden chafer, *Phyllopertha horticola*. The survey was designed to assess what bearing, if any, the management of the grassland had on the incidence of chafer attack. The survey showed that although permanent grass fields in the area were frequently infested leys grown on similar soils with similar management and manurial treatment were free from infestation. It was also found that permanent grass fields which were shut up for hay were more susceptible to attack than those which were used solely for grazing. A report has been sent to the provincial officers.

Advice was given on the design of a survey of brassica crops which are grown for stockfeeding in Wales. Information is being collected on the methods of cultivation, the yields and the utilization of the crops.

A survey is being made in conjunction with the Ministry of Agriculture of restored opencast coal sites ; the two main objects of the survey are to compare the condition of the land after restoration with the original condition before it was disturbed, and to make recommendations for improving technique of restoration for the future. The first stage of the survey, that of the enumeration of the

sites and the collection of preliminary material, has just been completed. During 1951 it is hoped to survey a sample of sites in more detail.

COLONIAL WORK

Mr. Hodnett was appointed on 1st August, 1950, to the post of Colonial Statistician. He is to work specifically on colonial problems. He has already dealt with a number of enquiries from colonial territories, including methods of calculating the sampling errors in a survey of population in Basutoland. He is now engaged in summarizing the results of previous colonial experimental work on sugar cane.

Mr. Church has also assisted in colonial work, particularly before the arrival of Mr. Hodnett. He gave advice on a census of population carried out by the Department of Economics and Trade, Sudan Government. He also paid a short visit to the West African Cacao Research Institute and other agricultural institutes in West Africa.

OTHER WORK

Mr. Dyke has continued to act as statistical adviser to the Advisory Entomologists. He has also been selected as representative for the Ministry of Agriculture on a Joint Committee with the Association of British Insecticide Manufacturers.

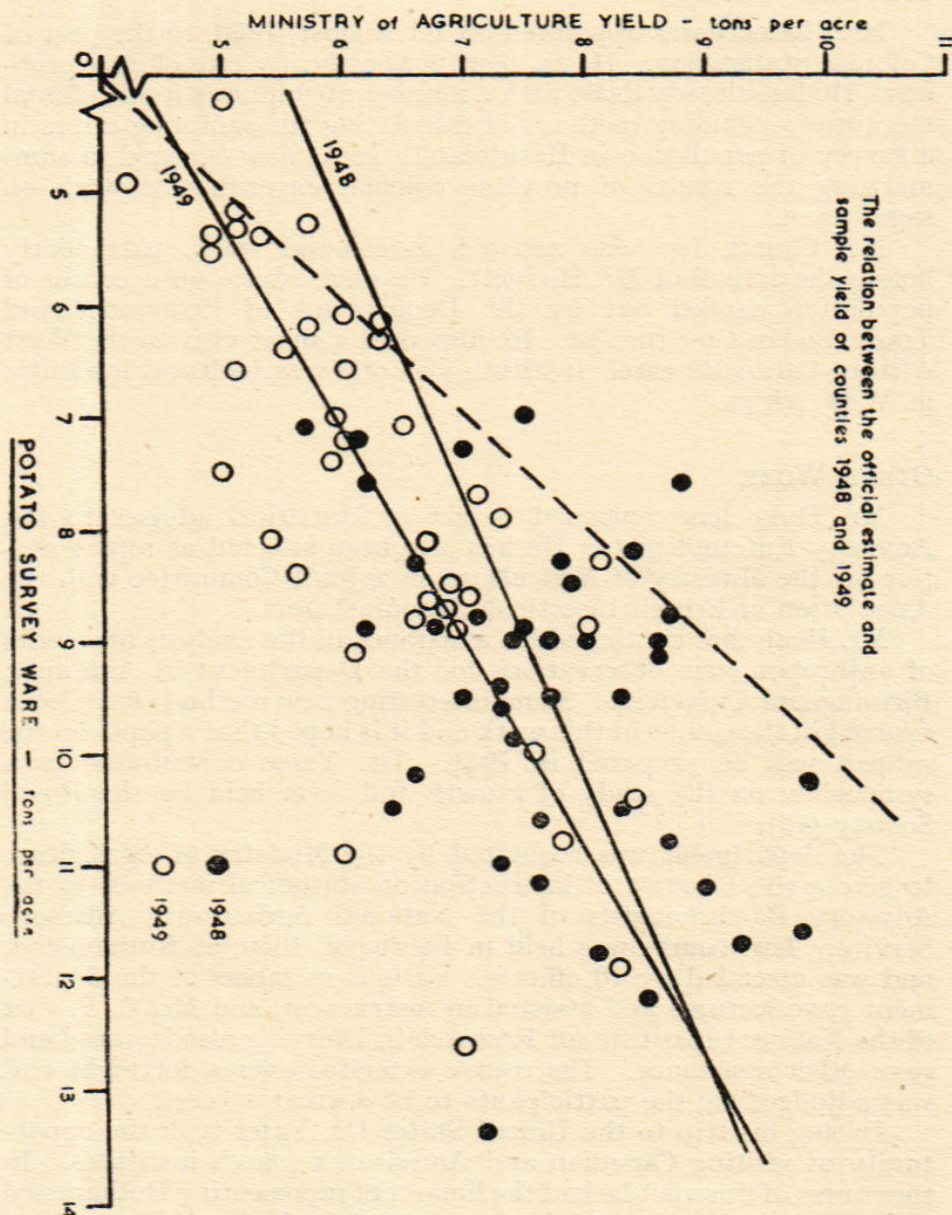
Mr. Healy has continued his assistance in the analysis of a series of anthropometric observations for the Department of Anatomy, Birmingham University. Some interesting new methods have been evolved in the course of this work and it is hoped that a paper on the subject will be prepared in 1951. Dr. Yates contributed to a symposium on the study of growth and form held by the Royal Society (42).

The department was requested by the Ministry of Agriculture to give a short course of instruction on statistical methods to the Advisory Bacteriologists of the National Agricultural Advisory Service. This course was held in February, 1950, at Rothamsted, and was attended by 10 officers. Various members of the department gave lectures and assisted in instruction, and Mr. C. P. Cox of the National Institute for Research in Dairying also lectured and gave other assistance. The course extended over a fortnight and was adjudged by the participants to be a great success.

During his trip to the United States Dr. Yates took the opportunity of visiting Canadian and American research institutes. In the course of this visit he had the honour of representing Rothamsted at the 75th Anniversary of the Connecticut Agricultural Experiment Station, the oldest agricultural experiment station in the United States.

Dr. Yates prepared a chapter for a symposium on world production of food (43), and a paper for the Journal of the American Statistical Society on the influence of R. A. Fisher's *Statistical Methods for Research Workers* which was published twenty-five years ago (44). Two reviews were also prepared by Dr. Yates (46, 47).

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HOLLERITH EQUIPMENT

The tabulator has now been in use for a year and a half and has fully proved its value. As mentioned in the introduction certain modifications increasing its scope and flexibility were installed in October, 1950. The idea of these modifications and the principles of their design originated with members of the department. Their main features are as follows :

1. Control of the distribution between counters of numbers read from the cards by means of information punched in more than one control column. Amongst other things this enables interactions of replicated factorial experiments to be calculated directly from the codes for the separate factors.
2. Increased control of the distribution of numbers between counters from the codes punched on a single control column. This makes possible the summation of products from single figure multiplication without sorting, and consequently replaces progressive digiting, a great advantage when a series of short runs of multiplications are required. A particular application of special value in survey analysis is in weighting by single figure weights, percentages, etc.
3. The alterations required for 1 and 2 also enable digital counting to be carried out without sorting.

The speed of the machine has also been increased from 80 to 150/100 cards per minute.

The classes of work that have been undertaken on the machine so far have been :

- (a) the analysis of surveys ;
- (b) the analysis of replicated experiments ;
- (c) multivariate analysis of various classes of biological material ;
- (d) the solution of mathematical distribution problems, etc., arising in biological research.

The installation of the modifications referred to above has greatly increased the scope and flexibility of the installation for the types of work with which we are mainly concerned. This is shown by the loading of the tabulator. Detailed records of the loading have been kept since the beginning of 1950 and are as follows :

			Days of work (average maximum 24 days)
January	..	..	12
February	..	..	12
March	..	..	13½
April ..	..	..	15
May ..	..	..	14½
June	..	..	12
July ..	..	..	7½
August	..	..	15
September	..	..	8½
October	..	..	21½
November	..	..	22½

The tabulator is now fully loaded, indeed for our class of work during the last two months it has been somewhat overloaded. Full loading is expected to continue.

From the experience of the last one and half years it is clear that the installation of Hollerith equipment under the direct control of scientific workers has been of considerable value. It has resulted in a much more enterprising and flexible approach to punched-card-work than was the case when all tabulations had to be carried out at a separate bureau. Moreover the modifications which have been installed would certainly not have been thought out had we not ourselves been in direct contact with the machine. These modifications are likely to have wider applications outside our own department ; an Australian worker who recently spent two months in the department has already approached the British Tabulating Machine Company with a view to arranging a similar installation in his department in Australia.

The installation of the equipment is also leading to the development of statistical methodology in new fields which had previously been neglected owing to lack of adequate computational facilities. For example, for the first time we have been able to tackle seriously multivariate analysis work. This type of problem is continually recurrent in biological and other research, but owing to lack of computational facilities in the hands of statistical research workers who are best acquainted with the problems involved and the theory already developed, the subject has hitherto made very slow progress.