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Statistics Department

F. Yates

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STATISTICS DEPARTMENT

F. YATES

The scientific staff of the department has remained unchanged, except that Sheila Cohen left to take up a post with Sylvania-Thorne Ltd. There were no new appointments.

N. E. G. Gilbert, statistician at the John Innes Horticultural Institution, has been seconded part-time (from December 1957) to assist in exploring the possibilities of using the electronic computer on the extensive mass of data that has been collected by the Animal Breeding Research Organisation, Edinburgh.

Eight temporary workers were accommodated during the year, four of them from overseas.

THE ELECTRONIC COMPUTER

The electronic computer has played an increasing part in the work of the department, and there has been a very substantial increase both in the volume and range of work. The greater output has been achieved without any marked increase in overtime working, the actual amount of overtime being 33 per cent above normal laboratory working hours, compared with 26 per cent for the period April–December 1956.

The computer itself has continued to give excellent service, and although the figures for reliability are not quite as good as last year, they remain very satisfactory. Details are given in Table 1.

It will be seen that the amount of time devoted to production has substantially increased relative to that devoted to programme checking. This is in part a reflexion of the fact that as our library of programmes has been extended more and more problems can be dealt with by existing programmes, or small modifications of them, and is in part due to increasing efficiency in programme writing and checking.

We have also made good progress in the organization and improvement of the auxiliary equipment on which the operation of the computer depends.

The punched-card reader, brought into operation at the end of 1956, has performed satisfactorily and has proved very useful in processing data already on punched cards, and in particular in the formation of sums of squares and products. We are, however, still awaiting a tape-to-card converter, which has now been on order for some time. Until this is obtained we cannot fully explore the potentialities of the machine for survey analysis.*

A Pye magnetic-tape transport store unit has been presented to the department by the National Research Development Corporation, and work is in progress on linking this up with the machine. The tape store control and power units have now been constructed,

* Delivered January 1958.

but we are still awaiting the delivery of some of the components required to set up the reading and writing circuits. Once this has been done, the specification of the input controls can be completed and their construction undertaken. If this unit proves satisfactory it will considerably extend the range of the machine in computations involving large bodies of data or lengthy programmes.

TABLE I
Record of machine operation over the period
1 January - 31 December 1957

Details of operation	Hours		Percentage	
	1956 *	1957	1956 *	1957
System modification (M)	94.3	16.5	5.3	0.6
Scheduled maintenance (S)	208.8	323.8	11.7	12.4
Unscheduled maintenance (U) †	46.7	209.4	2.6	8.0
Programme checking (C)	574.5	466.6	32.1	17.8
Production runs (P) ‡	757.4	1,430.9	42.3	54.6
Abortive efforts (A) §	47.8	58.9	2.7	2.2
Idle time (I)	58.4	114.9	3.3	4.4
Total machine hours (T)	1,787.9	2,621.0	100.0	100.0
Normal equivalent working hours (N)	1,416.0	1,977.0		
			1956 *	1957
Total time as percentage of normal laboratory time = $\frac{T}{N}$			126.3%	132.6%
% availability = $\frac{C + P + I}{T}$			77.8%	76.8%
% efficiency = $\frac{C + P + I}{T - S - M}$			93.6%	88.2%
% usage = $\frac{C + P}{C + P + I}$			95.8%	94.3%

* 1 April-28 August and 9 October-31 December.

† Unscheduled maintenance breaks down into:

- (i) 162.6 hours on the computer.
- (ii) 46.8 hours on the peripheral equipment.

‡ Production time breaks down into:

- (i) 1305.3 hours on numerical calculation.
- (ii) 125.6 hours on programme and library tape organization.

§ Abortive efforts break down into:

- (i) 34.0 hours claims against the computer.
- (ii) 24.9 hours claims against the peripheral equipment.

In order to improve the accuracy of the punching of the increasing volume of data dealt with by the computer, verification (instead of calling over from a printed record) has been increasingly adopted. Originally it was intended only to verify tapes and insert corrections later, and for this purpose a verifying punch was obtained. This procedure, however, proved unsatisfactory, particularly when handling large amounts of survey data, such as that of the Survey of Fertilizer Practice. The verifier has therefore been linked with an old output punch, and this assembly can verify, verify and re-punch, or punch, thus enabling an edited tape to be produced during verification. This system has shown itself to be reliable and trustworthy

and is now used for the preparation and checking of all the Survey of Fertilizer Practice tapes.

To reduce the amount of punching required for survey and similar extensive data the field use of marked-sensed punched cards is being investigated.

We have been considering possible methods of increasing the immediate access storage of the machine. (At present, apart from the accumulator and double-length register, there are only three single-word immediate access registers.) While it is unlikely that any very extensive modification will be an economic proposition, one very simple and attractive scheme which will add a further three immediate access registers without requiring any alterations to existing programmes appears to be possible. This will utilize the space in the cabinets made available by the new single-plate delay lines. These are being fitted in place of the old lines, which were giving increasing trouble. If this modification proves possible it will simplify the programming, increase speed and somewhat cut down the number of orders.

The life test on the special quality valves instituted last year has continued. At the end of 1957 less than 5 per cent of the ordinary valves included for comparison were still in service, whereas of the special-quality valves only about 7 per cent have been rejected. Some of these latter valves have now been in the computer for more than 4,000 hours. Special-quality valves suitable for computer use are now being manufactured as a standard line.

Satisfactory progress has also been made in the preparation of programmes. In addition to programmes prepared for specific jobs a number of new general programmes for performing statistical analyses of various types have been prepared, some of them of considerable complexity.

EXPERIMENTAL DESIGN AND ANALYSIS

Yates and Patterson carried out a preliminary examination of the results so far obtained in the six-course rotation experiments on varying levels of nitrogen, phosphate and potash at Rothamsted and Woburn, with particular reference to the estimation of errors and the possible relationships of responses to weather. A report of this examination is being published (12.9). An examination of the results of the Woburn ley-arable experiment undertaken by Dr. H. H. Mann and Boyd has been completed and a paper is in the press (12.4).

Boyd has carried out a thorough investigation of the differences in fertilizer responses of crops grown with and without farmyard manure. This has thrown considerable light on the somewhat curious results obtained by Crowther and Yates ("Fertilizer Policy in Wartime", *Emp. J. exp. Agric.* 1941), who found that the responses to inorganic nitrogen in the presence of farmyard manure were almost the same as those in the absence of farmyard manure. It appears that Crowther and Yates's findings were due to the poor performance of nitrogen at the low levels of phosphate and potash existing on many of the plots without farmyard manure, and that at adequate levels of phosphate and potash the response to nitrogen is

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considerably reduced by farmyard manure. A paper has been prepared, and will shortly be submitted for publication.

Boyd acted as joint author of the section on cultivations and manuring of the third edition of the Ministry of Agriculture's bulletin no. 94, on the growing of potatoes (12.1).

We have continued close collaboration with the National Agricultural Advisory Service (N.A.A.S.) on the design of crop and animal experiments. Patterson and Westmacott have been particularly concerned with this work. Boyd and Joan Anderson summarized the results of 38 $3 \times 3 \times 3$ NPK experiments on potatoes for the Soil Chemists of the N.A.A.S. Eastern Region. A report on this

TABLE 2
Analysis of experiments on the electronic computer

	(a) Number of experiments		(b) Number of variates	
	1956	1957	1956	1957
Rothamsted and other institutes ...	185	413	649	1,723
National Agricultural Advisory Service ...	309	623	784	3,030
National Institute of Agricultural Botany ...	189	217	268	288
Total ...	683	1,253	1,701	5,041

Details of variate analyses (1957)

	Randomized blocks and Latin split plots		3 ³	2 ⁿ
	split plots	Latin squares		
Rothamsted and other institutes ...	1,364	133	88	138
National Agricultural Advisory Service ...	1,961	554	205	310
National Institute of Agricultural Botany ...	288	—	—	—
Total ...	3,613	687	293	448

has been drafted and is under discussion with the Regional Officers. We have also done work for the Pea Growing Research Organisation and the Sea-Flooded Land Conference, and have collaborated closely with the Agricultural Research Council (A.R.C.) Statistics Group at Cambridge in the design and interpretation of experimental work on animals.

Leech prepared a report on the analysis of the 1956 field trials on chemical sterilizers for milking machines. These trials were organized by the National Institute for Research in Dairying (N.I.R.D.), and this report, together with the results of the laboratory tests at Shinfield, provided the basis on which the Ministry of Agriculture decided which materials should be finally approved.

We are still extending the use of the electronic computer in the analysis of replicated experiments, and the volume of work dealt with this year has shown a very substantial increase over that of last year. The number of experiments handled has been doubled and the number of actual analyses carried out has trebled. Four factors have contributed to this increase. First, because of the extension of our library of programmes the number of types of design which the electronic computer is capable of handling is steadily increasing.

Secondly, the number of research stations sending us work has somewhat increased. Thirdly, many of those who in the first place had current experiments analysed have subsequently asked if we could deal with some of their accumulated backlog of work which has been lying around awaiting analysis. Fourthly, many workers have taken the opportunity of having more thorough analyses done on the ancillary observations taken in the course of their experimental work. This last explains the greater increase in the number of variates analysed than in the number of experiments handled. The table on p. 178 shows the actual number of experiments handled and the numbers of analyses carried out (each variate analysed and each covariance analysis being reckoned as one unit). Great credit is due to Dunwoody and Emily P. Simpson for organizing the coding and punching of the large volume of experimental data handled this year.

SURVEYS

In 1956 the Fertilizer Manufacturers' Association suggested that they might co-operate in the Survey of Fertilizer Practice, thereby enabling it to be extended to a considerably larger number of districts. A joint scheme was consequently evolved for the 1957 survey, covering in all forty-five counties or parts of counties. Fifteen of these have been surveyed by the staff of the N.A.A.S. Regional Soil Chemists and the remainder by the representatives of the Fertilizer Manufacturers and Merchants.

Since this extension of the survey would have presented serious computing problems if handled by the previously current methods, it was decided to see if the work could be transferred to the electronic computer. This transfer was successfully effected by H. R. Simpson, who has been in charge of the whole of the electronic side of the work. This achievement marks a major step forward in the utilization of the machine for survey analysis. The speed of analysis has been more than doubled, which has proved particularly valuable because of the late arrival of much of the data. As an example, the results for two districts covering some 1,500 fields received on Monday, 9 December, were available the following Friday. If our ideas of using mark sensed cards for the recording of the original field data prove practicable the time of analysis should be further substantially reduced. It is intended to give this idea a field test in 1958.

A further advantage of the use of the machine is that once the tapes have been prepared additional analyses can be carried out by the machine very quickly. Thus for certain districts estimates have been obtained for straight and compound fertilizers separately; a programme has also been written which will produce a breakdown by previous crop and other factors.

A preliminary report based on the thirteen districts for which data had then been received was issued on 19 December (12.10).

The results so far available have allowed a close study to be made of farmers' current use of fertilizers, and at the same time information is being obtained from a number of districts not previously covered by survey. In the period 1953-57 overall consumption of fertilizers in England and Wales increased by about one-

quarter for nitrogen and one-half for potash, with little change for phosphate. The results so far available show that in all parts of the country the largest increase in consumption of nitrogen and potash per acre has taken place on arable crops. There have also been substantial increases on leys, but as yet there has been little change in the treatment of permanent grass, especially in those parts of the country where the acreage of permanent grass is large.

We have co-operated extensively with the National Institute of Agricultural Engineering in the design and analysis of various surveys. Much of this work has been done on the electronic computer and punched-card equipment.

The Ministry of Agriculture, Fisheries and Food (M.A.F.F.) has now started a survey on a national scale of the diseases of dairy cows. The sample of 1,500 herds for this survey was planned and drawn here except for the small samples for the Inverness and Aberdeen areas (12.3). Leech (and on the programming side, H. R. Simpson) have also continued the analysis of the results of the surveys of diseases of dairy cows in limited areas that had already been completed under the supervision of Dr. F. W. Withers. The analysis is now complete except for a critical analysis of certain results for which a programme for dealing with multi-way tables of quantal observations had to be written. A report with Dr. K. C. Sellers on the analysis of the second year of the survey of losses in breeding ewes in Yorkshire and Lancashire is in a similar position. The required programme (Yates and Leech) has now been completed. It is an extension of a programme for the analysis of multi-way tables of quantitative observations with unequal weights which has also been written (Yates).

Leech also assisted in the planning and analysis of several other investigations. The M.A.F.F., Health Division, was helped with the design of a system of records for a large field trial on a vaccine against Johne's Disease. The private cattle-breeding centres were advised on the planning of survey work into the factors affecting the fertility of cattle in Devon and Somerset, and some data were analysed on their behalf. A pilot survey of factors affecting cow fertility was also planned in co-operation with Dr. K. C. Sellers, Director of the Animal Health Trust, Farm Livestock Station. This survey was carried out through cattle-breeding centres operated by the Milk Marketing Board, and the results should indicate whether or not such a survey would be worth while and practicable on a larger scale.

ENTOMOLOGY

H. R. Simpson has continued to collaborate with Mr. W. H. Potts of the Colonial Office Tsetse Committee in a study of the possibility of tsetse control by the release of large numbers of male flies sterilized by gamma irradiation (12.7). He has also assisted Mr. J. Bowden of Ghana in the analysis of some survey data on the Cacao Capsid. This involved fitting negative binomial distributions, for which a programme was written for the machine.

Marjory G. Morris has continued her co-operation with members of the Entomology Department. In particular she has co-operated

with R. M. Dobson on studies of the emergence and longevity of adults of the wheat-bulb fly. A joint paper is being prepared. She has also carried out analyses on experimental data on the frit fly of oats for the N.A.A.S. and of some frit-fly data for the Entomological Department of the Imperial College of Science.

GENETICS

We completed the work for Dr. J. W. B. King, Animal Breeding Research Organisation, Edinburgh, on the data on pigs from the Danish Progeny Testing Stations. The last part of this work was much facilitated by its transference to the electronic computer when the card reader became available (Westmacott). As mentioned in the General section, we have recently made arrangements for undertaking more extensive computing work for this organization.

Gower has continued his work with Dr. E. C. R. Reeve, Institute of Animal Genetics, Edinburgh, on the effect of linkage and selection in in-breeding (12.6). He has also undertaken a Monte-Carlo type investigation into population changes when two competing species are present for Dr. P. H. Leslie, Bureau of Animal Population, Oxford. Two models were investigated, and a paper describing the results will be prepared.

H. R. Simpson completed his work in co-operation with Dr. J. H. Renwick, Galton Laboratory, on the estimation of linkage from a variety of human pedigree data (12.8).

COLONIAL WORK

We have continued our advisory work for Commonwealth workers and have done some work on the electronic computer. Three Commonwealth workers have studied in the department for varying periods.

OTHER WORK

Gower has written a programme for G. Brown (Pedology Department) for the calculation of indices and interplanar spacings of X-ray reflexions from the cell constants of crystals. The use of this programme disclosed some errors in a book which Brown is editing. J. H. Rayner (Pedology) gave a short account of our crystallographic programmes to the Conference on Biological Structures and Computational Methods held in London, 1956 (see above, p. 67).

Lipton has developed a programme for fitting the logistic curve

$$y = A - \log_e(1 + Be^{-kt})$$

This was required by Mr. J. A. Nelder of the National Vegetable Research Station. He has also written a programme for evaluating the integral of the bivariate normal distribution over a non-rectangular region, required by Dr. P. S. Hewlett (Pest Infestation Laboratory, D.S.I.R.) and Dr. R. L. Plackett (University of Liverpool) in their development of a unified mathematical theory for quantal responses to mixtures of drugs (*Nature, Lond.* **180**, 712,

(1957)). Lipton and Nelder are also carrying out an investigation into the Newton-Raphson iterative procedure for solving least-square equations.

Healy has continued to assist various medical departments, including Birmingham University Department of Anatomy, The Nuffield Blood Group Research Centre, the London University Institute of Child Health and the Central Public Health Laboratory. C. C. Spicer of the Central Public Health Laboratory has been studying the programmes and use of our machine with a view to utilizing it on various problems with which he is concerned.

Lipton has continued his work with Dr. K. L. Blaxter of the Hannah Dairy Research Institute on the Cattle Efficiency Project of the Agricultural Research Council. There is, however, a good deal more to be done before the value of the project can be finally assessed.

Lipton also carried out an investigation into the relation between the length of sampling interval and the accuracy of the estimation of milk production in conjunction with Mr. L. K. O'Connor of the Milk Marketing Board. Systematic sampling of milk yield, fat yield and solids-not-fat yield at intervals of 7, 14, 28, 42, 56 and 63 days was carried out on each of eighteen lactations. A preliminary report on the accuracy of estimating lactation fat per cent has been published (12.5). A more detailed paper dealing with other estimates is being prepared.

OVERSEAS ASSIGNMENTS

Yates spent two and a half months in India during the winter of 1956-57. The first month was spent at the Indian Statistical Institute as a member of an International Review Committee set up to review the work of the Indian National Sample Survey. The other members of this Committee were Sir Ronald Fisher, Dr. M. H. Hansen (U.S.A.), Professor T. Kitagawa (Japan) and Professor A. Linder (Switzerland). The last 6 weeks were spent at the Statistical Wing of the Indian Council of Agricultural Research, New Delhi, making a review of the progress of the agricultural research programme on which he and Dr. Finney advised three years previously. Yates also attended the Third Meeting of the Sub-Commission on Agricultural Research of the F.A.O. European Commission on Agriculture which met in Paris during April.

Church completed his assignment in Ethiopia, where he was organizing sample surveys for the collection of basic agricultural statistics.

Patterson is at present on a 6-months visit to the Institute of Statistics, North Carolina. He is mainly engaged on advisory work on crop experiments and research on change-over trials in animal husbandry experiments.

CONFERENCES, LECTURES, ETC.

The year has seen the establishment of the British Computer Society. Yates is a member of the Council of the Society and Rees is a member of a number of its Committees. Rees took part in

much of the preliminary discussion prior to the formation of the Society.

A number of members of the department have given lectures on scientific and statistical matters.

Healy and Lipton attended the 30th Session of the International Statistical Institute, which was held in Stockholm in August.

A course on statistical method was given by members of the department at the end of January to members of the staffs of the N.A.A.S. Experimental Husbandry Farms and Experimental Horticulture Stations. The course lasted a fortnight, and there were sixteen participants.