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ROTHAMSTED RESEARCH

Report for 1972 - Part 1

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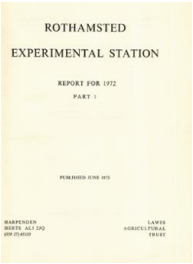
ROTHAMSTED
EXPERIMENTAL STATION
REPORT FOR 1972
PART 1

Statistics Department

J. A. Nelder

J. A. Nelder (1973) *Statistics Department ;* Report For 1972 - Part 1, pp 225 - 234 **- DOI: https://doi.org/10.23637/ERADOC-1-127**

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STATISTICS DEPARTMENT

J. A. NELDER

The provision and development of programs for statistical analysis were again an important part of the Department's work; these programs are being extensively used and although we have not succeeded in pleasing all the people all the time the scope of the facilities provided has been appreciated. The theoretical work reported makes much use of the computer as a tool and is aimed at providing general methods for the analysis and interpretation of data. The practical applications described show the range of problems the Department is consulted about and the contribution that statistics is able to make in their solution.

Statistical programming

The Mark 2 Genstat system of programs has had its first full season of work and has been much used by many ARC institutes as well as ourselves. The version maintained by the Edinburgh Regional Computing Centre on their IBM 370 machine has been distributed to the Cambridge University Computing Laboratory and also to the Atomic Energy Research Establishment, Aldermaston, where principal co-ordinate analysis, a facility available on Genstat, was needed.

As is inevitable on a system of this size, some bugs were discovered during the year and these were mended in the five releases. Experiments we did with methods of output from Genstat enabled the Computer Department to make time savings of about 30%. Because of faster overlaying of program segments there was another 30% improvement in throughput when high-speed drums were installed during the autumn. The user can now define how much working space he needs for each job when he runs it; this allows small jobs to be put through more rapidly, and avoids the need for a large and a small version of the system. Error control is now kept as much as possible within Genstat instead of being surrendered to the operating system. (Simpson, with Guthrie, Computer Department)

Additional Genstat facilities made available during the year were mainly in matrix algebra and multivariate analysis. The three matrix types, rectangular, symmetric, and diagonal, may now be mixed in operations and the matrix-product operation may have either of the operands in transposed form. The latent-roots-and-vectors directive was extended to facilitate the solution of $(\mathbf{A} - \lambda\mathbf{B})\,\mathbf{x} = \mathbf{0}$ and a new directive for canonical variate analysis was added. (Gower and Banfield) A looping directive was also provided, in which the loops cannot only be nested in the usual way, but can have several lists running in parallel for each loop. (Nelder)

The Genstat language is now sufficiently general for new procedures to be written in it directly. For example, a method of performing a canonical correlation analysis was devised using existing Genstat directives. (Banfield) Because the Genstat language is interpretive this solution may not be efficient for frequently used programs in the sense of minimising run-time. However, compared with Fortran, Genstat will often provide a better solution to a programming problem with less system overheads and fewer runs before the program works.

Genstat Mark 3. A Mark 3 version is being developed to generalise the syntax of the

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Genstat language, improve the compiler, remove some restrictions on job size and add to the algorithms with the least possible increase in the size of the system. This new version of Genstat has made steady progress, though development has frequently been slowed down by difficulties with the 4/70 operating system.

Compiler. By re-writing the compiler using a syntax analyser based on a one-one precedence grammar there are fewer restrictions on what the user can write in his program. Despite allowing greater generality, the compiler itself is shorter. (Simpson, Nelder and P. Leech)

Diagnostics. Error messages have been improved, and the positions of faults found by the compiler are indicated. (Nelder and P. Leech)

Garbage collection. A new routine to retrieve waste space in the system has been included, and is directly available to users. (Wedderburn and Rogers)

Macros. A macro facility added to Mark 3 will allow the Genstat program writer to construct his programs more easily from standard blocks developed and named in advance. Only 35 extra Fortran statements were needed to provide this facility. (Nelder)

Output. The user can control the grid size in graphs and match the scales on the two axes; coincident points in scatter diagrams are marked or listed beneath. (Alvey)

Calculating facilities. New functions have been added, including the log likelihood for four distributions, the median and simple regression coefficients calculated over variates. Matrix inversion has been generalised to unsymmetric matrices and the program dealing with table operations simplified. (Alvey)

Regression. The matrix of sums of squares of products can be formed within groups if required. Facilities for the specification of models for regression are being extended and will eventually have the generality of those already provided for the analysis of designed experiments. (Wedderburn)

Cluster analysis. Directives for cluster analysis can now be freely mixed with other directives. (Lauckner)

Multivariate analysis. Singular-value decomposition of a matrix, the basis of many algorithms, and an algorithm for the rotation of factors using either of two criteria have been implemented. (Banfield and Gower)

Documentation. The single existing Genstat manual has not proved entirely satisfactory, and there has been a persistent demand for two levels of documentation for the user. A new reference manual will give a full but succinct description of the language and facilities and will be supplemented by a series of user's guides, covering different aspects of the system in a more introductory way.

Transfer to CDC computers. In collaboration with Miss Margaret Ansell of the Statistics Department of Imperial College, we have begun a feasibility study on the transfer of Genstat to the CDC 6000 and 7600 series. The basic word structure of these machines is very different from the ICL System 4, and they also have a different method (rather less

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flexible) of segmenting large programs. Preliminary results show that if some parts of the system are modified the transfer will not be difficult.

Other programs

Several large statistical programs, written in Fortran, were obtained during the year and successfully mounted on the 4/70. Small, but lethal, differences in Fortran dialects, and other machine dependencies, often make such mounting a non-trivial task. Two programs dealt with multi-dimensional scaling techniques, and came from Mr. R. Sibson of King's College, Cambridge, and Dr. J. Kruskal of the Bell Telephone Laboratories at Murray Hill, New Jersey. (Banfield and Jackson) Mr. M. R. B. Clarke of the Institute of Computer Science, University of London, kindly supplied his program for factor analysis which uses a new approach to the maximum likelihood solution. We also tested on our machine a program VARIMAX, taken from the book 'Multivariate Data Analysis' by W. Cooley and P. Lohnes (New York, Wiley, 1971), which performs factor rotation. (Banfield)

Maximum likelihood program. The optimisation routine was thoroughly revised, and new ideas on the handling of non-positive definite matrices (by modification of the Choleski inversion procedure) and on the treatment of constraints were incorporated.

Compilation of derived variate instructions made it possible to provide a syntax for user's models in high level language rather than in Fortran. Operands are variates, parameters and scalars, and the user provides a sequence of instructions to evaluate working variates. Likelihoods for normal, binomial, Poisson or multinomial models may be specified, and linear parameters may be separated out. Transformations are readily achieved, and likelihood contour diagrams produced. This facility has made it much easier to study *ad hoc* models without compiling special subroutines, although the user now has responsibility for initial values and step lengths.

The contour diagram was made available to users for plotting data or fitted surfaces, and was also adapted to plot likelihood remainder functions and contours of linear parameters in non-linear models.

Various new models were added. Maximum likelihood regression for quantal variates was provided. A generator for random normal deviates allowed data to be simulated. (Ross, Jones, Kempton and Payne)

Cluster analysis. An independent version of the package incorporated in Genstat allows rather larger jobs to be run, with up to 300 units and 200 variates. This was used to analyse several large sets of data. Features include fixed and free format input, similarity matrices, hierarchical and non-hierarchical clustering, principal coordinate analysis, keys, and the relationships between the structures obtained. Some of these features will be incorporated in Genstat. (Ross and Lauckner)

Construction of keys. The Fortran computer program constructs biological keys to identify species by means of tests. The key may be constructed either branch by branch or depth by depth. For each method tests may have any number of responses and species whose response to some tests is undetermined may be included. A diagram is drawn of the key and the key may also be output in words if required. (Payne)

Statistical theory

The shape of the likelihood surface in the neighbourhood of its maximum is important both in designing algorithms to find the position of the maximum when no explicit

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formula exists, and in making inferences about the uncertainties to be attached to the estimates. Many optimising algorithms used in locating the maximum will converge in a few steps when the surface is exactly quadratic; in particular the classical Newton–Raphson method converges in just one step. With non-quadratic surfaces various modified Newton methods have been proposed that produce converging estimates of the best-fitting quadratic surface in the neighbourhood of the maximum. Ross has revised and improved his strategy, which is based on doing successive factorial experiments on the likelihood function to estimate a locally best-fitting quadratic surface. The attainment of the maximum can often be accelerated by making local transformations to convert the surface into a more tractable form. To be fully effective such transformations should be discovered by the algorithm itself rather than imposed by the programmer. Ross has studied remainder functions, i.e. the difference between likelihood functions and their best local quadratic approximations, with a view to producing such automatic transformations to accelerate attainment of the maximum. In one dimension (line minimisation) rational functional transformations appeared to be more effective and robust than fitting cubics, but in practice both methods require the accurate estimation of third differences and therefore high precision arithmetic and a large step length. In two dimensions, remainder functions reveal asymmetry and non-linearity, and suggest possible bivariate transformations.

A method of continuous re-transformation was devised for exponential models. After each iteration scaling factors are adjusted so that the non-linear parameters return to their initial position. The shape of the likelihood function improves at each iteration and convergence is accelerated. The method is independent of the user's choice of scale, and non-existence of a solution is detected by slow convergence. Growth curves may also be fitted by this method.

Correlation functions between fitted values were used to study the position of points whose ordinates provide orthogonal estimates of parameters. Exact solutions exist for polynomials, and the analogy helps in the study of non-linear curves. Practical solutions were found for exponential and double exponential curves, logistics and rational functions, and also for the two-compartment model.

A measure of non-linearity is the discrepancy between the observed and expected likelihood at the 95% confidence limits based on parameter estimate and standard error. Inverse interpolation procedures may be used to compute exact 'support' limits where the likelihood contour cuts the parameter axis. This is important for models such as dilution series where the asymmetry is very marked. (Ross)

The generalised linear models described in the *Rothamsted Report for 1971*, Part 1, have been developed further. In particular a method of fitting has been worked out for situations where the model is specified in terms of constraints on the fitted values rather than in terms of parameters representing effects, etc. An example is provided by contingency tables with symmetric margins. The estimation procedure can be described in terms of two complementary models, the fitted values from either equalling the residuals of the other. A paper has been prepared. (Wedderburn)

The Gauss–Newton method of fitting non-linear models with Normal errors has analogues when the errors come from other distributions of the exponential family, such as the binomial, Poisson, or gamma distributions. The appropriate generalisation has been studied. (Wedderburn)

In the analysis of covariance, adjustment of the means may cause a reduction in the error variance per plot, but this is somewhat offset by an increase in variance caused by the non-orthogonality introduced by the covariance adjustments. The concept of covariance efficiency factors was developed to measure the average loss of information caused by this non-orthogonality. These are now incorporated in the Genstat output for

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the analysis of variance, and give a useful indication of the extent to which standard errors of individual comparisons may differ from the average for all such comparisons. (Wilkinson)

Fisher's fiducial theory of inference has remained controversial since his death, with the discovery of apparent paradoxes in its application and uncertainties about the rules of procedure. In a joint project with Professor A. T. James of the University of Adelaide, the problem of combining information on means and variances, of which the recovery of interblock information in incomplete block designs is a special case, was re-examined and new fiducial distributions derived. The distributions were calculated and plotted, using Genstat, for several special cases and approximations usable in general are being sought. When individual estimates of a mean are discrepant compared with their own standard errors the fiducial distribution for the combined estimate can be bimodal. The work so far underlines the importance of establishing at each stage of the argument what quantity is to be taken as given in the sense that subsequent inferences are made conditional on that value. A principle of fiducial conditioning has been formulated and its implications are being studied. (Wilkinson)

A mathematical model was developed to explain the observed phenotypic divergence between populations, when migration was assortative for phenotype, and to estimate the genetic component of the divergence. A paper in which the model is successfully fitted to both experimental and observational data has been completed. (Kempton)

A graphical technique for comparing curves was devised. Cluster analysis of residuals revealed whether alternative curves that fitted data equally well, according to their residual sums of squares, gave similar or different patterns of residuals. This technique helps to distinguish between systematic and random patterns of residuals, and points to aberrant data. A similar technique may be applied to multiple regression models. (Ross)

Practical applications

Exploratory analysis. Some examples are given from a wide range of topics.

During proliferation the mildew fungus *Erisiphe graminis* on barley and wheat passes through four distinct states; for plants grown in controlled-environment cabinets at different temperatures, several models have been fitted to the relative numbers in each state at different times after infection. The models are characterised by a transition matrix whose elements are the probabilities that an individual fungal spore or its derivative will pass from its current state to the next state or die. The aim is first to estimate these probabilities and relate them to the ambient temperatures, and then to try to extend the model to the variable temperature found in field crops. The preliminary results are encouraging, some transition probabilities being temperature-independent over a wide range. (Payne, with Bainbridge, Plant Pathology Department)

A study of relationships between night illumination and light trap catches in the tropics has been completed. Average catches of some species were more and of others much less on moonlit nights. The hours of night when individual species are most active can be inferred from differences in average nightly catch over the lunar cycle. Most of these differences may be explained by differences in trap effectiveness caused by night illumination, but some species are evidently more abundant on moonlit nights. (Church, with Bowden, Entomology Department/ODA)

The relation between winter weather and the amount of sugar beet yellows the following August was studied, and predictions from weather data were compared with those based on aphid counts earlier in the season. The consistency of the relationships in different parts of the country and in periods before and after the widespread introduction of

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insecticides was also examined. A paper has been prepared. (Lauckner, with Marion Watson, Plant Pathology Department, and Heathcote, Broom's Barn)

A model was derived connecting eruption of first molar tooth in cattle to age; it belonged to the class of generalised linear models (*Rothamsted Report for 1971*, Part 1) with one extra non-linear parameter. A paper has been prepared. (Leech and Wedderburn, with Mr. A. H. Andrews of the Royal Veterinary College)

The multivariate facilities in Genstat were put to a variety of uses.

Principal component analysis was applied to data on the amounts of certain chemical compounds in 32 aphid species to see if an *a priori* classification of the species into groups could be reproduced. (Banfield, with Griffiths and Callow, Insecticides Department)

The rotational fitting techniques were used to measure the consistency between judges' assessments of sides of beef, using data collected by the Meat Research Institute; a principal co-ordinate analysis on the consistency statistics resulted in a two-dimensional representation of the judges' abilities. (Banfield, with Mr. J. M. Harries of the Meat Research Institute)

Principal co-ordinate analysis was also found useful in analysing data on Bantu languages and on isotope ratios. (Banfield)

Further examination of results of multi-level experiments done by ADAS Soil Scientists on spring barley has shown consistent effects of site factors on the form of response to N especially in relation to the rate of response/kg N with sub-optimal dressings. In 17 experiments in South-western England 1965–68, the nitrogen responses of most crops were well represented by split-lines, but smooth curves fitted better when the barley was affected by leaf diseases. (Boyd and Sparrow, with Mr. P. Needham, ADAS Soil Scientist, Cambridge)

The additional insight gained from multi-level experiements with nitrogen emphasised the need to modify the conventional 3^3 design. Previous experiments showed that, even with the potato crop, interactions between non-zero fertiliser levels usually followed quite simple patterns and as 40 plots per site is usually considered the maximum for series of experiments on commercial farms, we proposed a new type of experiment consisting of a single block of 36 plots and testing six amounts of each nutrient N, P and K in 1/6 replicate. Reasonably balanced designs were selected (no fully balanced design exists) and the results analysed using the constant-fitting program. ADAS Soil Scientists at Bristol, Reading and Wye completed six experiments with barley on chalk soils. A report prepared for the Soil Scientists' Agricultural Investigations Committee showed that except at one site there were almost no effects of P or K. Standard errors per plot ranged only from 4 to 9%. Preliminary results of a similar series of experiments with potatoes indicate that with this more responsive crop interactions were not negligible, but, as expected, followed a quite simple pattern. (Boyd, Sparrow and Dyer, with Mr. P. A. Johnson, ADAS Soil Scientist, Wye)

Surveys. The change-over of computers in April meant that a good deal of time was spent during the year in learning how to operate the general purpose programs necessary for survey analysis on the 4/70, and in introducing others to these facilities. Both Genstat (particularly for the analysis of small surveys and observational data) and Yates' General Survey Program are proving effective, and processing of larger bodies of data will be expedited now that adequate sort-merge facilities are usable on the 4/70. Genstat conveniently produces 'scatter diagrams' and this is a useful practical advance in much of this work.

Fertiliser practice. The series of country-wide surveys in collaboration with ADAS Soil Scientists and the Fertiliser Manufacturers Association was continued. Soil samples

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taken in the 1969 and 1970 surveys gave the first information on the nutrient status of soils in England and Wales from a fully random sample of fields. Tabulation (using the General Survey Program) and reporting were completed within a month of receiving the complete soil analysis data at Rothamsted, and a brief paper is in preparation. In contrast to the situation soon after the war, routine advisory samples now give a good representation of soils in the whole country for major plant nutrients, e.g.

pH (water):	<5	5·0–	5·5–	6·0–	6·5–	7·0+	
			Percentage of samples				
Random samples	1	5	16	22	22	34	100
Advisory samples	2	5	17	24	22	30	100

(Church and Hills)

Rothamsted Insect Survey. Daily records of insect catches for more than 200 sites over the last four years comprising about 100 000 cards are now punched and available on magnetic tape. Because tapes had to be repeatedly updated, existing programs for editing and interpreting the records proved too inflexible so a small suite of specific programs was written. Tape corruption running at about one job in five has entailed repeated copying and relabelling of tapes. Analysis and interpretation of the data are continuing. So far, maps of the distribution of individual species over the country have shown clearly defined seasonal trends, and suggested interactions between different species. The structure of the whole population at a site has also been studied, and the relationship between the diversity, total species present, and their relative numbers investigated.

Other surveys. Consulting work on the analysis of pesticide surveys (with Mr. J. M. A. Sly, MAFF Plant Pathology Laboratory), and the ADAS Plant Pathologists' cereal foliar disease surveys (with Mr. J. King, MAFF Plant Pathology Laboratory) continued, but regular users of survey programs on the 4/70 can manage more of their own data processing with the new general programs.

A survey of the incidence of wild oats and blackgrass and of herbicide use on cereals in the United Kingdom was planned for the Weed Research Organisation in collaboration with ADAS Crop Husbandry Officers, and main tabulations were completed for a sample of 600 farms. Other work included tabulations for the Potato Marketing Board survey of seed tuber diseases (with Hide, Plant Pathology Department) and for a survey of Docking Disorder in sugar beet (with Cooke, Broom's Barn). (Hills)

Recommendations for sampling glasshouse soils were made as a result of an investigation by ADAS Soil Scientists into the variation in nutrient content within and between individual beds and between houses. (Tong Kwong Yuen)

Experiments

Routine analysis. For the first time for some years fewer results were analysed, especially those from within the Station, probably because some customers are using the computer themselves, a development we have actively encouraged. Work from overseas via ODA-supported activities was also less, partly because more critical scrutiny of experimenters' requests led to fewer analyses. In September we started monitoring a 1/10 sample of all routine jobs primarily to find bottle-necks but also to see whether the potentialities of Genstat in general, and the ANOVA package in particular, were being fully exploited. In the first two months about 100 jobs per month were being done for ADAS with an average time from receipt to despatch of 17 days (12 working days): the survey showed ways of shortening the average turn-around time. It is also clear that we

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need to make experimenters more aware of the facilities we can now provide, so that they can use them to best advantage. (Dunwoody, Dyer, Ryan, Sowray and Todd)

Crop experiments. The department assisted in summarising several series of field experiments and other investigations including results of manurial experiments with potatoes on silt soils (6), experiments on intensive cereal growing at Rothamsted and on Experimental Husbandry Farms. With Draycott and Durrant (Broom's Barn) we reviewed the published information on the effects of K and Na fertiliser for sugar beet. Responses to the two nutrients proved less closely related than had been supposed and instances of perfect substitution were rare and probably fortuitous. Responses to K were much decreased in dry springs and, especially with April sowings, when the crop was sown soon after giving fertiliser. (Boyd and Ryan)

Livestock. Further work was done for the Ruminant Energy Requirements Working Party, which concluded that a slightly modified form of the ARC metabolisable energy system should replace the Starch Equivalent system. These findings were reported to a Joint Conference on Nutrient Standards in April 1972 (1). (Lessells)

Subsequent critical studies have indicated the need to consider further modifications to the ARC system. The predictive reliability of metabolisability, implied by the model, is not substantiated by available calorimetric data, nor can metabolisability be measured directly under practical advisory conditions. The comparative testing of other predictive measures which might be more accurate and convenient is possible only if intake is expressed in units of gross energy. This change would greatly simplify the model and is therefore desirable even if metabolisability is retained as the predictive measure. The review of calorimetric data has cast some doubt on assumptions concerning the evaluation of mixed feeds, and on the use of sheep data to predict energy retentions of cattle. The form of the relationship between energy intake and retention also needs clarification.

In addition to the design and analysis of animal experiments, other work for ADAS has included the investigation of indirect methods of assessing the feeding value of dried grass, and the investigation of a scoring technique to predict future performance of ewes. The interim results of a large-scale investigation comparing Charolais cross-bred cattle with native breeds were analysed. (Lessells and Currie)

Commonwealth and Overseas

Statistical work supported by the Overseas Development Administration involved data from experiments in Bolivia, British Honduras, Fiji, Ghana, Kenya, Lesotho, Malawi, Nigeria, Sabah, Sarawak, Tanzania, Uganda, Zambia. Again varieties and fertilisers were the principal concern, and the range of crops included bananas, cocoa, coffee, cotton, grasses, groundnuts, kenaf, maize, oil palm, sesame, siratro, sorghum, sugar cane, teak and tobacco. During the year some 20 research workers from overseas called for statistical consultancy, and training was given to three overseas biometricians.

The Department provides a service for routine statistical analysis, and also investigates statistical problems arising therefrom, as shown in the following examples:

Some agronomists have applied different treatments to sets of two or three whole replicates of balanced lattice designs in variety trials, hoping thereby to extract more information from them. The full least-squares solution to this problem was compared with the analyses of the constituent simple or triple lattices, and with the orthogonal split-plot analysis ignoring the blocks. It was concluded that when there were interactions between treatments, the split-plot analysis could be seriously misleading.

In field trials for screening varieties for resistance to a wilt disease, observations have

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the form $\{(r/n - (r_0/n_0)\}$, the suffix zero denoting the wilting of control plants included in each plot. The effects of angular and logit transformations, with and without weights were examined, and it was concluded that a weighted analysis was necessary and that the logit scale gave slightly the better fit.

Cotton breeders in Uganda are interested in genotype × environment interactions. They have data from variety trials in a number of districts and in a number of special environments contrived on research stations over several years. The data are being examined (a) graphically, (b) by regressions on site means, and (c) by joint analysis of variance if appropriate.

A cocoa entomologist has sample insect counts on a number of species for periods ranging from two to eight years. He is interested in using Fourier analysis to identify periodicities in the data and, where two species have roughly the same period, to try to interpret this and the phase difference between them. The longer series have given some interesting results, but the two-year series are too short to identify satisfactorily the periodicities he is interested in. (Wimble, Robinson and Macpherson)

Collaboration continued with Dr. R. Webster of the Soil Survey, Oxford, on various aspects of principal component and canonical variate analysis relating to soil studies made in Borneo, and on planning the collection of soil data in Australia for future multivariate analysis. (Banfield)

Staff and visiting workers

R. D. Jones, Glenda Robinson, K. C. Ryan and J. D. Starkie left. I. S. Macpherson, R. W. Payne, Anne Sowray and Agnes Victor were appointed.

At the invitation of Professor M. E. Muller, Nelder attended a meeting of the Advisory Committee for the Department of Computing Activities of the World Bank held in April in Washington, D.C. He also visited Bell Telephone Laboratories in Murray Hill and gave a seminar on generalised linear models. He gave a lecture on this subject at Imperial College and also spoke on the design and analysis of experiments at the University of Manchester Institute of Science and Technology and at a seminar held at Gregynog, residential educational centre of the University of Wales. He chaired a Seminar on Applications of Optimisation Techniques in Agricultural Engineering held at the National Institute of Agricultural Engineering, Silsoe. Nelder and Wilkinson attended a Symposium on R. A. Fisher's Contributions to Inference in Scientific Reasoning, held at Gonville and Caius College, Cambridge, and Nelder gave a paper.

Nelder was joint organiser with Professor D. R. Cox and Dr. A. M. Herzberg of the Mathematics Department, Imperial College, of a one-day meeting on the Design and Analysis of Experiments held at Imperial College to mark the occasion of Dr. Yates' 70th birthday. Papers were given by eminent statisticians including Dr. Yates himself. One hundred and thirty people attended in spite of a one-day rail strike which coincided with the event.

Lectures on Genstat were given as follows by members of the Genstat programming team: a course of ten lectures to Rothamsted staff; a course at the Edinburgh Regional Computing Centre lasting three days; Genstat/Multijob lectures in which we cooperated with members of the Computer Department and which consisted of lectures covering two consecutive days given at East Malling, Glasshouse Crops Research Institute, Grassland Research Institute, National Vegetable Research Station, National Institute of Agricultural Engineering, Long Ashton Research Station and the Weed Research Organisation. (Alvey, Gower, Leech, Nelder, Rogers, Ross, Simpson, Wedderburn, Wilkinson, Wimble) Nelder also lectured on Genstat at Bradford, Bristol and Dundee Universities and at Imperial College.

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Wimble spent 2½ weeks in Kenya advising the Ministry of Agriculture on the organisation of biometrical services for its Research Division, and 3½ weeks in Sabah as a consultant on data-handling and statistics.

Leech visited Ibadan to advise on the planning of animal disease surveys, and Malawi and Nairobi to discuss the effectiveness of the campaign of vaccination against bovine tuberculosis. He also attended the International Summer School on Computers and Research in Animal Nutrition and Veterinary Medicine, Elsinore, Denmark.

Professor A. T. James of Adelaide University spent two months in the department working on a project with Wilkinson and gave a colloquium. Mr. A. N. Sadovski of the N. Poushkarov Institute of Soil Science, Sofia, spent seven months in the Department on an FAO Fellowship. Three other overseas workers spent varying periods in the department.

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