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ROTHAMSTED RESEARCH

Rothamsted Experimental Station Report for 1983

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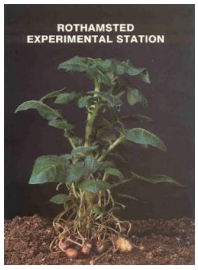

Biomathematics Division

J. A. Nelder

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INTRODUCTION

The new Division of Biomathematics comprises the Computing Unit (RESCU) and the Statistics Department. Its formation should enable us to organize for the Station a comprehensive service for the effective collection, handling and interpretation of data. We can advise on the design of experiments, hardware for data collection, software for subsequent data storage, display and analysis, methods of statistical analysis and interpretation, and subsequent archiving of both basic data and summaries.

The Computing Unit has responsibilities for maintaining the central computing facility, for advising on non-numerical software, and for training, which is an important activity if effective use is to be made of the tools we have, whether of hardware or software.

The Statistics Department continues to maintain and develop statistical software, and its programs are being increasingly used, both inside and outside the AFRS. A large

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component of its work remains the provision of a statistical service for the Station, for ADAS, and (through ODA support) agriculture overseas. Research into applicable theory has involved work on generalized linear models, experimental design, multivariate analysis, and non-linear inference. The rest of this Report illustrates the various aspects of the Division's work, without attempting a complete coverage of all our activities.

COMPUTING UNIT

In this first full year of existence, the major emphasis has been on preparing for the new computer system, training the users, transferring work from the old system, and collaborating with Departments in specifying systems hardware and software to meet their research objectives.

In July a Digital Equipment Corporation (DEC) VAX 11/750 system was delivered and will provide the basis for a new general purpose computing facility for Rothamsted. This machine is part of the AFRC Computing Centre's network of mini-computers, replacing the ICL System 4.

In addition to the DEC VAX service, the Unit supports many microcomputers, used for dedicated equipment control, data capture, and general-purpose work, also two Jacquard systems which are used both for word processing (all Departments) and data entry (Statistics).

The VAX system. The Rothamsted VAX system comprises an 11/750 processor with 2 Mbytes memory, two 250 Mbytes exhangeable disc drives, a 300 lines-per-minute graphics-capable printer, a synchronous link to the AFRC X25 computer network and 24 asynchronous lines for terminals. An internal dial-up facility has been provided for local use and for Broom's Barn, with two further lines for off-campus locations such as Soil Survey of England and Wales (SSEW) regional offices. Visual display units (VDUs), hard-copy terminals, microcomputers, a flat-bed plotter and a high-resolution colour display are connected to the system.

An X25 network-link gives access to The British Telecom Packet Switch Service (PSS), and so to UK Universities and international databases. This network is currently used by Rothamsted to access specialist software elsewhere.

The VAX system is normally available continuously except during periods needed for archiving or system maintenance. The system serviceability has been good, approaching 98% on average. A figure of 99% is expected after the equipment has settled in properly.

Graphics. A major effort has been mounted to provide good graphics packages which appear to be machine independent. Three levels of graphics software are planned, one for easy use by the non-programmer, a second with easily called routines for the occasional programmer, and a third with more complex features for the experienced programmer. The last requirement has been met on the VAX with the implementation of the GHOST package, release 6 (Bicknell); this has also been interfaced to the colour display, where it is used both for the display of spatial data and for work on image analysis. A complete graphics suite has also been developed for CP/M-based microcomputer systems (Summerfield) and is running on five microcomputers within Rothamsted.

An easily used menu-driven package has been developed to allow for quick graphical displays of most tabulated data. (Bicknell)

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Databases. Much effort has been put into developing the VAX Datatrieve relational database package for Rothamsted users (Lessells, Summerfield, Thomas). Datatrieve has been used for Entomology moth data, SSEW soils data, Insecticides data collections, Biochemistry chemicals lists, PEP meteorological data, and the Library serials list (under development).

Microcomputers. The recent spectacular developments of microprocessor hardware allow much computerized control and data logging to be done in the laboratory where before it was either impossible or too expensive. We have concentrated on selecting the right hardware, and software tools have been developed (Moore) to ease the development of application software. Most microcomputers must be connected to the VAX for off-loading laboratory data; file-transfer software has been written for all Rothamsted micros with CP/M. (Higgins, Moore)

In connecting laboratory equipment to microcomputers, bar-codes have proved very efficient for handling samples; work with the Entomology Department has led to the development of four further dedicated computer systems employing bar-codes. (Summerfield and Verrier)

The Epson HX-20 portable computer is being tested for field recording in mild weather. (Verrier)

Data Preparation. The service performed 5·6 million key depressions in entering data for 936 separate tasks. We use a key-to-disc system developed by the Unit (Verrier, Lessells) which can handle both entry and verification of complex data, including hierarchically structured records. Media conversion tasks and disc recovery procedures have also been developed (Pallett, Moore). Currently about 20 floppy discs per month are processed by this service.

Staff

Angela Barrett left the Unit. Angela Barrett, K. E. Bicknell, Denise J. Pallett and P. J. Verrier attended the DEC User Group Conference at Lancaster University.

K. E. Bicknell is a member of the GHOST Technical Committee and the UK Eurographics Chapter Committee.

STATISTICS DEPARTMENT

Practical applications

Collaboration with the Insecticides Department has continued on the practical use and further development of a simulation model for herbicide movement in soils. Modifications to correct for predictions of excessive herbicide are being investigated. (Baker, with Nicholls, Insecticides)

Traditional designs for experiments on take-all have a few large plots, each of which is sampled in several places. The distribution of take-all is usually very patchy and so the precision of such designs tends to be rather poor. Thus it was decided to investigate designs with small (35 cm×35 cm) plots, each the size of a single sample. The treatments, six candidate methods of controlling take-all, were arranged in balanced incomplete blocks, each containing three treatments plus a control. Blocks of complementary treatments were paired (to form a complete replicate) and the

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block-pairs were scattered at random through the experimental area. (Each block-pair was thus about 2 m^2 compared to about 50 m^2 for plots in the usual designs.) At both Rothamsted and Woburn, the block-pairs were very much more variable than the blocks. This justifies the use of small plots, although for sites in take-all decline, with the disease more evenly distributed, slightly larger plots could be used. (Payne, with Henden and Hornby, Plant Pathology, Bateman, Insecticides and Brown, Soil Microbiology)

The possible use of the Box-Jenkins (ARIMA) models for time-series analysis have been investigated for sequences of catches of *Chrysoperla carnea* and several aphid species from the Rothamsted suction traps. Standardized catches for 11 years were used. For the aphid data first differences gave an effectively random sequence, i.e. a (0, 1, 0) model was adequate; for *C. carnea* autocorrelation at lag one was important after first differencing, and a (1, 1, 0) model was chosen. The cross-correlations between the differenced series showed no detectable structure in any of the years. The implications of these results need further study. (Perry and Clark, with Bowden, Entomology)

The new ICP Spectrometer has been tested to determine interference between certain pairs of elements found in soil and plant samples. Results from test solutions were modelled by weighted quadratic regressions whose parameters are now used in the machine to adjust for interference when analysing samples with unknown constitution. (Lane, with McGrath and Pope, Soils and Plant Nutrition)

Experiments to measure the flight-track of over 600 male pea moths, flying through a crop to several equally-spaced pheromone traps aligned along the mean wind direction, were consistent with the key assumption of a mathematical model (*Rothamsted Report for 1982,* Part 1, 284) that the resultant flight of a population of such moths is due upwind with respect to the mean wind direction. This result emphasizes the striking difference between pea moth flying within a crop and other moths flying over open ground (*Rothamsted Report for 1982,* Part 1, 96–97). (Perry, with Wall, Entomology)

The multidisciplinary experiment on factors limiting yield of wheat has now been analysed and the results published (Todd and Church, with Prew, Field Experiments Section, and others). Work is continuing on subsequent annual experiments.

Routine analysis. The number of analyses of data has remained almost unchanged for both Rothamsted and ADAS work, with a turn-round time of 5–6 days. With the termination of the AFRCCC data preparation service some extra work is now being accepted from other AFRS institutes (Dyer, Smith and Todd). The Jacquard data-entry system was upgraded with considerable eventual improvement in performance.

Work for ADAS

Crop experiments. Work continued on the SB15 trials of urea on winter cereals, and a series of national fungicide trials started in 1982 (Bailey). Summaries were produced of the 1982 results of two series of experiments—SB06, nitrogen on spring barley, and SB10, nitrogen on winter wheat. The results for non-sandy mineral soils confirm the new ADAS recommendations for these soils. (Dyer)

A national series of trials on the fertilizer equivalent of nitrogen in cow slurry for conserved grass was carried out in 1980–82 over 29 sites. For slurry applied early (March–April) the N was about 35–40% as effective as mineral N, as measured by the first silage cut. For slurry applied after the first cut (May–June), second silage yields gave a figure of 20–25%. (Dyer)

Four years of data on Pentland Squire potatoes at Terrington EHF have been examined to determine economic optima. A limiting exponential model was found to be adequate with extra terms for year-to-year differences and flood damage. (George and Baust)

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An interesting problem arose from an oilseed rape trial. Mr B. Bastiman, High Mowthorpe EHF reported yields fluctuating by about 30% in successive plots. Other experiments showed similar but smaller fluctuations. The cause seemed to be differing amounts of seed held in the combine at the end of each plot, depending on the direction of cut. A general increase in precision was given by a covariance correction adjusting for direction of combining.

More worrying is the implication that measurements recorded will be the effects of mixtures of the current and previous treatments. A technique has been developed to estimate the proportion of mixture and thence adjusted values for the moisture and oil contents. The revised estimates of oil content often differ significantly, where previous estimates did not. Further work is being done on the effect, which may appear with other combined crops. (George, Dyer and Baust)

Nutrition chemistry. A new carbohydrate fractionation technique has been tested to determine the repeatability of laboratory results. This proved acceptable for the neutral detergent fibre but not for acid detergent fibre. Further 'ring tests' on *in vivo* and *in vitro* digestibility of hay and straw have been carried out to discover if the between-laboratory error of the latter can be reduced; however results are still poor. (Altman)

Livestock experiments. A course for livestock experiments on the role of statistics in experimentation proved highly successful. (Altman, Bailey, Murray and Kirby)

A national investigation into the effect of worming dairy-bred yearlings at yarding indicated a small, non-significant increase in winter growth rate for animals treated with an anthelmintic drug. (Altman)

Poultry and pig data received since 1974 have been archived on magnetic tape and made self-defining. All important experimental details can now be printed on the analysis sent to clients and data-sets can be retrieved without accessing other records. This will facilitate data-sharing and the setting-up of animal data-banks. (Spechter)

Experiments analysed include a study of fattening pigs at Terrington EHF, to assess the value of liquid potato feed and the effects of early feeding of gilts on their litter production. (Spechter)

Surveys

Sugar beet surveys. Using information for 1971–82 from Specific Field Surveys organized by British Sugar in collaboration with Broom's Barn, the stability of estimated relationships between pre-harvest samples and deliveries to factories has been examined and an empirical equation for predicting deliveries proposed. Discrepancies between pre-harvest yields and actual deliveries are attributable to biases in both sampling and area reporting, growth after sampling and harvesting losses. (Church and Gnanasakthy)

Fertilizer practice. The Survey of Fertilizer Practice was continued in England and Wales on a sample of about 1300 farms and extended to Scotland, where a sample of 250 farms was surveyed in 1983.

The system of direct entry of survey data developed by RESCU to replace punched cards has involved substantial reorganization of our procedures for validating, amending and merging data subfiles. (Church, Leech and Elsmere)

Representative soil sampling. This survey started in 1969 and samples about 500 fields on some 120 farms annually. The same fields are surveyed at five-yearly intervals,

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allowing trends in soil nutrient status to be estimated. Data from six years have been validated, and lime requirements reported. (Church, Gnanasakthy and Elsmere)

Theory

Quasi-likelihood. Quasi-likelihood is a way of specifying the error component in a generalized linear model solely in terms of mean and variance. Wedderburn's original definition (see *Rothamsted Report for 1973,* Part 1, 225) allowed the variance to be a function of the mean, but gave no way of comparing different possible variance functions on the same data set. This limitation has now been overcome by extending the definition to include the estimation of the dispersion parameter. All the components of a generalized linear model, covariant, link function and variance function can now be embedded in parametric families and prior choices tested for relevance. (Nelder, with Dr D. Pregibon of Bell Laboratories, Murray Hill, NJ., USA.)

Confidence limits for parameters in curve fitting. Estimated standard errors of non-linear parameters may give a misleading impression of the range of uncertainty. To obtain exact likelihood-based confidence limits one must find the maximum and minimum value of each parameter consistent with the data. An approximate solution to this problem uses independent stable ordinates (see *Rothamsted Report for 1978,* Part 1, 310), giving a near-quadratic residual sum-of-squares function. The simplest general method of transforming back to the original parameters is to iterate on linear approximations to the transformation equations. The method agrees well with the exact method when errors are small, but fails of course when parameters can become infinite, giving open-ended confidence regions. (Ross)

Zeros in contingency tables. The literature is confusing, and a commonly made adjustment of degrees of freedom for random zeros in contingency tables invalidates the analysis. Despite statements to the contrary, maximum-likelihood estimates for the expected values always exist, even with random zeros, and a simple method has been found for amending the usual algorithm to handle such cases more cleanly. Many widely-used statistical packages analyse zero entries incorrectly. (Baker and Lane, with Dr M. R. B. Clarke, Queen Mary College)

Irredundant sets in diagnostic keys. Given a set of taxa and their results with a collection of discrete-valued tests, an irredundant test-set allows all the taxa to be identified but contains no redundant tests. Methods are known that construct all the irredundant sets for a particular set of taxa and tests, but there may be too many sets for practicable computation. An improved sequential method has been devised to select one irredundant set, also a method for constructing further sets that allows each test in the selected set to be replaced. (Payne)

Biplots. The biplot methodology developed by Professor K. V. Gabriel (see e.g. Biplots in *Encyclopedia of Statistical Sciences, I,* Wiley, 1982) has been extended in two ways. First the form of biplot for symmetric and skew-symmetric matrices has been established. Secondly a three-dimensional biplot with interesting structure has been developed for a wide class of additive/multiplicative models for two-way tables with rank three. The points representing column-entries and the points representing row-entries each lie in their own plane and the angle between these planes, and certain directions within them, have interpretations that help in constructing appropriate models and in revealing anomalous data (Gower). The above theoretical results underlie a three dimensional colour-graphic computer plot whose development on the Sigma 5000 has started. (Bicknell, Gower)

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Variance-mean relationships. A drawback to the study of samples from animal populations, in which the variance is usually proportional to a power, β, of the mean (Taylor's law), is the lack of a frequency distribution with this property for general values of β. If x_i denotes a set of two-parameter Gamma variates with constant coefficient of variation, ν, and a range of values of the other parameter, λ_i, an initial investigation showed that the set of variates $(\log_e x_i)^c$, c constant, approximately obeyed Taylor's law. To first-order β should equal $2(c-1)/c$; however, further work is required. (Perry)

Statistical programming

Genstat. Release 4.04 was made available in a preliminary form to System 4 users in March; a revised version was completed by the end of the year. Versions for the VAX, Prime and IBM were produced at Rothamsted, and tapes were sent to 13 potential converters; of these conversions, that for the GEC41 series was completed and work on the CDC 7600, Telefunken and VAX(Unix) was well under way. By December 1983 the number of sites with Genstat had risen to 243, an increase of over 20% on the previous year. (Simpson)

Support. Courses on Genstat were given abroad during the year at the Agricultural Institute in Dublin, and in Harare, Izmir (Turkey) and Naples; at home we gave two courses at Rothamsted and one each at Guildford, Bristol and Saffron Walden (Digby, Dixon, George, Lane, Murray, Nelder, Payne, Riley, Ryder and Simpson). Genstat was demonstrated at several overseas conferences. (Nelder, Payne, and Lane, with staff of the Numerical Algorithms Group)

New version. Work began on a major restructuring of the Genstat language to make it more internally consistent, easier to use (particularly interactively), and more powerful. At the same time the implementation aims to reduce the amount of special code required by the compiler and to make for easier maintenance, while keeping the interpreters and algorithms as little changed as possible. The preliminary specification allows for trees of pointers to be referenced, subsets of elements to be referred to directly, and for closed procedures with parameter lists to replace the existing run-time macros. (Digby, Dixon, Lane, Nelder, Payne and Simpson)

Macro library. This is being reorganized under the editorship of Miss Jane Bryan-Jones of the Cambridgeshire College of Arts and Technology. The macros dealing with multivariate analysis have been extensively rewritten, so that for groups of analyses there are now tool-kits of individual macros, each of which either does a particular type of analysis (but with no printed output) or provides output of a type standard to all the analyses in the group. This makes the multivariate macros far more flexible, obviating the need to specify large amounts of code. New methods of analysis are easily provided because the output macros already exist. Those requiring standard analyses may use the analysis macros unchanged. (Digby, Harding).

Genkey. A major use of this program during the year was the production of identification keys, descriptions and tables of characteristics for the 473 currently recognized species of yeasts. Keys were generated automatically, complete with instructions for the Oxford University Lasercomp typesetter, by Genkey and other programs, using data recorded on a specially designed form. (Payne, with Dr J. A. Barnett of the University of East Anglia and Dr D. Yarrow of the University of Delft.)

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MLP. Development of version 3.08 continued, and the algorithms for Parallel Model Analysis were improved. The user language has been extended and a new function for incremental arithmetic allows recurrence relationships to be programmed very concisely, with applications to general frequency distributions, transition models and differential equations. The algorithms for curvilinear functional relationships (both variables subject to error) and confidence limits for parameter estimates, described above, were incorporated. By December, 41 licences had been issued. Versions are now available for 17 machine ranges. (Ross, Harding)

GLIM3. This program is now installed at over 700 sites in 43 countries. During the year a version was made for the Sirius Micro, and also a CP/M-based version. A revised version was developed including provision for plotting on a high-resolution graphics device. (Baker, with Mr Alan Reese of the University of Hull)

GLIM4. The name PRISM was abandoned because of trademark clashes. Some coding has continued and the data structures, command mechanism and set of commands available have been specified. Much time has been spent on rethinking the structure of GLIM given current ideas on user–computer interaction. Terminal and graphics devices now support a wide variety of input and output methods (cursors, menu selection, figure drawing, movement etc.), enabling a more natural and flexible dialogue with the application program. Current research concerns the implementation of these dialogue methods in GLIM, and its implication for the program's input/output. (Baker)

Graphical routines. Version 7.0 from Queen Mary College of the Graphical Kernel System (GKS) has been mounted on the Prime. Device drivers for the Datatype and Tektronix were modified and tested.

Two high-level routines, using GKS, were developed. One can produce pie-charts in a wide variety of styles in a device-independent manner. The other produces contours from a set of points either regularly or irregularly spaced; contours can have varying line styles and be labelled along their paths. Titles and annotation of axes are also available. (Baker, White and Mr J. Kemmler, visiting worker)

Microcomputers. Collaboration has continued with ADAS on the use of micro-computers, and the provision of statistical software. We are committed to a disc-reading service for transmission of data between the machines to be installed at the EHFs and EHSs and our VAX at Rothamsted. (George)

Overseas

The ODA-funded Unit continued to provide biometrical services to overseas agricultural research (Preece, Ryder and Riley). Two overseas visits were made: by Ryder to Zimbabwe in April and May, when he mounted Genstat on computers in Harare, and by Riley to Turkey in October, when she gave a course on the use of Genstat.

The amount of overseas work handled was similar to that in 1981 and 1982, and related as usual to a wide range of field crops; countries involved included Bangladesh, Belize, Bolivia, Botswana, the Gambia, Indonesia, Kenya, Lesotho, Malawi, Paraguay, Sudan, Tanzania, Thailand and Zambia.

Work from the Falklands Islands Agricultural Research & Development Centre increased greatly during the year. It included analyses of agronomy experiments, experiments on the growth of sheep and cobalt supplementation of sheep's diet. Advice

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was given on the design of a trial to assess how winter grazing by geese affects spring pasture production. (Riley)

Ryder continued to analyse seed-variability data for Dr P. B. Tompsett (Royal Botanic Gardens) and to process environmental data from Botswana.

Riley continued her work on statistical aspects of intercropping research. She generalized the now well-known Land Equivalent Ratio to a form usable when yields are combined from several different intercropping systems for two crops. She continued to investigate the connection between (i) the analysis of indices of combined yield and (ii) the bivariate method of analysis when used for data transformed to square roots or logarithms.

The promotion of good practice in the collection of data, and in the use of statistics in the interpretation and presentation of results, continues to form an important part of the Unit's work. To this end Ryder has been working on a set of guidelines for the layout and general presentation of numerical tables in research reports and scientific papers, while Preece has developed a series of brief accounts of selected statistical topics, each of which has been the subject of a discussion meeting within the Department. The topics discussed have included important practical aspects of statistics in the analysis of data, and we plan to convert some of the texts into a set of statistical notes suitable for distribution to ODA advisers and Technical Co-operation Officers. These notes may well find wider uses.

Staff and visiting workers

P. K. Leech was awarded an Honours degree in Mathematics and Statistics

Annette Pooley and Jane Dockeray left, S. Kirby, T. Dixon and Gul Baust joined the Department. Wendy Barthorpe transferred from the old Computer Department.

J. A. Nelder visited Stanford University, California, in July, going on to Bell Laboratories, New Jersey for two weeks, and then to Toronto, Canada to the ASA Conference there. He introduced an EEC seminar in Luxembourg on the application of mathematical models to the analysis of large surveys. J. A. Nelder and J. C. Gower gave invited papers at the 3rd International Symposium on Data Analysis and Informatics at Versailles.

R. A. Bailey was elected a member of the International Statistical Institute. J. C. Gower was a delegate to the 44th Session of the International Statistical Institute in Madrid.

P. G. N. Digby, C. J. Dyer, R. P. White and A. W. A. Murray attended the Joint Meeting of the British and Netherlands Regions of the Biometrics Society at Wageningen.

J. A. Nelder, J. C. Gower, B. J. George, P. Lane, G. J. S. Ross, R. A. Bailey, R. P. White and Annette M. Pooley attended an International Conference sponsored by the University of Sheffield on 'Regression, Modelling and Data' where J. A. Nelder and G. J. S. Ross gave invited papers.

J. C. Gower and G. J. S. Ross participated in the International Statistical Workshop on 'Functional and Structural Relationships' at the University of Dundee in August.

In August R. W. Payne visited Agriculture Canada in Ottawa, going on to the ASA Conference in Toronto; he also gave an invited paper at a conference on Information, Questionnaires and Fuzzy Sets at Tours.

J. C. Gower spent 8 weeks in Australia with CSIRO, mainly in Adelaide but also visiting Canberra, Melbourne and Brisbane where he gave an invited paper at the Australian Mathematical Society's Annual Conference.

The Third International Genstat Conference was held at Orsay near Paris in October and attracted 86 participants from 13 countries. The 28 speakers included P. G. N.

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Digby, J. C. Gower, P. W. Lane, J. A. Nelder, R. W. Payne and D. A. Preece; T. J. Dixon, H. R. Simpson and A. D. Todd gave demonstrations.

J. Riley lectured at a course on Management and Analysis of Statistical Data for overseas students at the University of Reading.

Dr N. Carter of the Game Conservancy Board has been with us for the past year continuing his work on the effects of predators on cereal aphid populations. Professor R. M. Patterson of Auburn University, Alabama, visited the Department from June to November.

PUBLICATIONS

Computing Unit

BOOK

JONES, F. G. W. (& JONES, Margaret G.) (1984) *Pests of Field Crops*. 3rd Edition. London: Edward Arnold.

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JONES, F. G. W. (1983) Weather and Plant Parasitic Nematodes, *EPPO Bulletin*, **13**, 103–110.

YATES, F. (1982) William Gemmel Cochran, 1909–80. *Journal of the Royal Statistical Society*, A, **145**, 521–523.

PROGRAM AND SYSTEM GUIDES

021/83 A Brief Guide to Using ZSID.
022/83 The CP/M Command DOUBLE.
023/83 Microfin Development System, RESCU modifications.
024/83 Jacquard Word Processor—Various Procedures.
025/83 S+PN MIDAS System.
027/83 The Micromation Multi-I/O Board.
029/83 RGSP Mk. 2 under VAX/VMS.
031/83 NAG Mk. 10 on the VAX 11/750.
032/83 CP/M Graphics Library vsn. 2 User Guide.
033/83 CP/M Graphics Library System Description.
037/83 How to use the MIDAS 3D System.
038/83 Vector Graphics Precision Analogue Interface Board.
039/83 S+PN MIDAS System No. 2
040/83 Epson FX-80 Serial Printer.
042/83 VAX SPITBOL and Conversion from RESBOL.

Statistics Department

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