ROTHAMSTED RESEARCH

Rothamsted Experimental Station Report for 1987

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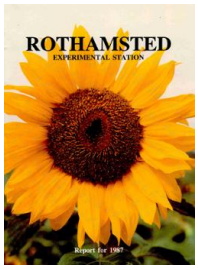

General Report

Rothamsted Research

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GENERAL REPORT

In the Report for 1986 reference was made to impending organizational changes throughout the Agricultural and Food Research Service (AFRS). In the past year the process of rationalizing activities within eight new Institutes has continued. Rothamsted is a component part of the Institute of Arable Crops Research (IACR), together with Long Ashton Research Station (LARS) (closely associated with the University of Bristol), the Unit of Insect Neurophysiology and Pharmacology (UINP) (housed with the Department of Zoology of the University of Cambridge) and Broom's Barn Experimental Station near Bury St Edmunds and supported in its role of research for the sugar beet industry by levy funds administered by the Sugar Beet Research and Education Committee. Professor Ken Treharne, currently Director of Long Ashton, has been appointed Director of Research designate for IACR to succeed Sir Leslie Fowden FRS from 1 July 1988. Dr Trevor Lewis was confirmed in the appointment of Head of Station at Rothamsted from 18 May 1987. Ways of integrating the staff and research programmes at the component sites of IACR are under active consideration. At 1 July 1987 the former Soil Survey of England and Wales (now the Soil Survey and Land Research Centre (SSLRC)) completed a planned transfer of staff and activities to the Cranfield Institute of Technology (CIT) on their new site at Silsoe College. Some few staff will be based at Rothamsted for a time and scientific co-operation will be maintained for the future. The Lawes Trust has retained the copyright of the Soil Database, a valuable asset of the SSLRC, which will be transferred to CIT at a later date.

With the consolidation of the structure of the new Institute the intention is to produce an annual Report covering the highlights of the Institute's programme rather than the details of activities as a whole, during each year ending 31 March. The format of any supplementary Reports for individual sites has yet to be decided.

During October and November the research programmes at Rothamsted, together with those of other components of the Institute, were the subject of review by a Visiting Group appointed by AFRC under the chairmanship of Professor Sir David Smith FRS. Conclusions will be known early in 1988.

Lawes Agricultural Trust. The Rt. Hon Lord De Ramsey KBE TD DL resigned as a Trustee. Lord De Ramsey was first appointed as a representative of the Royal Agricultural Society of England on the Trust Committee in 1964. He served additionally as Treasurer from 1970 until 1978, when he was appointed Chairman, an office which he held until 1981. He was appointed as a Trustee in 1978. The Trust and the Trust Committee are privileged to have been helped and guided by Lord De Ramsey over this long period. Such wise help and guidance benefited Rothamsted and its staff in many different ways, and was always freely and generously given.

Professor Sir Richard Southwood FRS, Pro-Vice Chancellor and Vice Chancellor Elect of the University of Oxford has been appointed by the Royal Society to fill the vacancy created by Lord De Ramsey's resignation.

Staff. The following senior staff appointments were made during the year: Mr A.E. Johnston—Head of Soils and Crop Production Division (as from 17 August); Dr B.R. Kerry—Head of Entomology and Nematology Department (as from 1 September); Dr R.A. Leigh—Head of Crop Production Department (as from 1 December).

Dr T. Lewis and Mr J.C. Gower each already Divisional Heads at Rothamsted were respectively appointed as Head of Crop and Environment Protection Division and Biomathematics Division within IACR.

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Dr Gillian Thorne retired at 31 May after a distinguished career as a plant physiologist spanning 37 years.

Dr R.K. Scott who had been head of Broom's Barn since 1977 left at 31 August to become Professor of Agriculture at the University of Nottingham. During his period at Broom's Barn Scott had vigorously reorganized and redirected many of the research activities and maintained and improved the close co-operation with, and service to, the Sugar Beet Industry.

A.J. Barnard of the Field Experiments Section died prematurely and tragically. He is sadly missed by many former friends and colleagues.

Dr R.M. Sawicki was elected a Fellow of the Royal Society on 19 March.

Recognizing the widened remit of activities of the RES Computing Unit the title of 'Computing and Electronics Department' was approved from 1 November.

Buildings. The Station's Conference Hall was inaugurated on 6 April when the Director of IACR, Sir Leslie Fowden FRS, gave an address entitled 'A Glimpse of the Past and a Glance at the Future', followed by a dinner at Rothamsted Manor. Those attending included representatives of the Lawes Agricultural Trust Committee and other financial sponsors. Finance for the building was provided by grants and donations from over fifty foundations, industrial and commercial companies, public bodies including AFRC and individual donors from the UK, Europe, United States and Japan. Almost two hundred donations towards the equipment and furniture were made by staff, former staff and others associated with Rothamsted in the past. The building has proved to be a very effective setting for meetings and conferences benefiting Rothamsted and other sectors of the scientific community, and for meetings of scientific and learned societies. A number of local organizations have also been able to use the hall, thus providing a positive contribution by Rothamsted to the life of Harpenden and district.

No major building projects were in hand during the year and the opportunity was taken to undertake extensive and much needed maintenance to buildings including roof repairs and external painting.

Finance. The last Report referred to continuing erosion of the level of support for research, and the loss of seven redundant posts, as well as a number by retirement and resignation. It had been anticipated that no further post losses would be needed after March 1987. However, the level of support predicted from March 1988 was reduced in real terms, one contributing factor being a new Civil Service pay agreement covering all staff in the Science Group. It became necessary to identify some twenty posts which could be declared redundant or would not be filled—the seventh time such action had been taken.

At the time of writing (29 December) the level of support to be received from 1 April 1988 has been revised again and the effect on number and timing of post losses is being evaluated. It should be noted that the number of Science-Group complemented posts has fallen from 424 to 265 between April 1981 and April 1987.

Continuing progress is being made in attracting funds from sources other than the AFRC as the following tables shows:

	£
Year to 31 March 1985	544 000
Year to 31 March 1986	713 000
Year to 31 March 1987	1 052 000

However, sponsorship from such sources is essentially selective and temporary in nature, and poses problems for the management and planning of research.

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Scientific interchange

The Friends of Rothamsted. The Friends of Rothamsted organization now has just over 300 members, and continues to provide a valuable forum for exchange of ideas between the scientific staff and the agricultural industry. We are most encouraged by the high proportion of the membership attending meetings at Rothamsted—120 in January and 107 in June. In January members heard illustrated presentations on Rothamsted's work on plant genetic engineering and on herbicide research at Long Ashton, as well as reports on the field experiments they had visited the previous summer. The summer meeting was marred by appalling weather, which curtailed visits to four important trials featuring wheat, barley, oilseed rape and spring beans. However, detailed explanations followed by talks on strategies to cope with insecticide resistance in aphids and houseflies infesting pig units were given later in the Conference Hall.

The year has also seen increasing co-operation between the Friends of Rothamsted and Long Ashton Members Association (LAMA).

Rothamsted Farming Service on viewdata. We have continued to provide topical data on pests, diseases, soil and crop nitrogen and summaries of field experiments for both Prestel Farmlink and Agviser; the latter was acquired by Farmlink in the autumn. During the year efforts have been made to improve presentation and design to make our information more 'user friendly'. We plan to include material from Long Ashton, initially field experiment results, in the new year, when it will become the IACR Farming Service.

Rothamsted staff have participated with poster displays at a number of agricultural shows and scientific meetings, notably the Royal Show, Cereals '87, BASF Velcourt Arable Farming and the Hertfordshire Show when we took the opportunity to demonstrate viewdata.

Library. As books and journals continue to increase in price at a rate well above inflation and as funds become more restricted the Library has recognized the need to promote and exploit existing resources and services to the full. Online access to information has become more cost effective with a greater choice of databases, faster communication speeds, more sophisticated software and the refinement of searching techniques. Use of the online service has grown and must continue to do so if we are to ensure that our research staff do not suffer a corresponding restriction in their access to new and important scientific information.

Overseas visits and visitors. Overseas contacts were maintained through visits by 80 staff to scientific meetings and longer exchange visits abroad. Some of the longer visits took R. Webster to South Africa to investigate the spatial distribution of soils and vegetation in forests, C.J. Rawlinson to India to discuss collaborative research on disease problems of oilseed crops, D.S. Jenkinson to Australia and New Zealand to centres involved with nitrogen cycling and wheat production and R.M. Sawicki also to Australia for consultations on pyrethroid efficacy and resistance. Under the Academic links with China Scheme the British Council approved a new three-year link with the Beijing Academy of Agricultural and Forestry Sciences and exchange visits between staff of the Crop and Environment Protection and Plant Science Divisions have already taken place, alongside exchanges between the Station and Nanjing Agricultural University under an existing link. Sir Leslie Fowden FRS made an extensive tour of universities and publicly- and industrially-funded research centres in Japan.

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We welcomed 63 visiting scientific workers for a month or longer from 31 countries—identical figures to the previous year—and 45 of the current longer-term workers are registered for PhD studies.

Weather and crops. Taking all aspects of the extremes of weather into account, the year was probably more difficult for the farm programme than 1986. January was unusually cold but February and March milder and dry, enabling spring drilling to be completed in reasonable time. In April, potatoes were planted in a spell of the warmest spring weather for 40 years. Thereafter frequent periods of unseasonable weather contrived to hinder rather than help crop spraying, growth and harvest of crops, though a brief dry spell in early July produced some reasonable hay. The cereal harvest extended from the beginning of August to late September with grain generally of poor quality, and was followed by the wettest October ever recorded at Rothamsted since 1853 with 198.7 mm of rain. The previous wettest October was in 1865 with 187.5 mm rainfall. Fortunately, we suffered lightly in the great storm on the night of 16 October losing only eight mature trees. Clearing work further hindered a delayed autumn planting schedule.

It is a pleasure to record the Station's appreciation of the farm manager and his staff for coping over such a difficult season.

Research highlights

Over the past few years there has been a gradual increase in emphasis on biotechnological work within the Station's programme. Aspects of this approach, initiated in 1979 in the Biochemistry Department, have now been taken up by crop protection scientists and soil microbiologists, partly in response to support from external funding agencies who regard this broad area of study as potentially lucrative, but largely because of the exciting opportunities it offers, in the long term, for improving the efficiency of crop production in ways hitherto barely imagined. For example, in the not too distant future, it should be possible to provide farmers with simple kits to diagnose disease and pest problems in their own fields, and in the longer term to produce plants with highly desirable growth or nutritional characteristics, as well as resistance to many of the organisms that limit yields.

Nevertheless, in this 'high tech' age it is salutary, and perhaps necessary, to be reminded of the fact that for the foreseeable future the practice of large-scale agriculture and the appearance of the countryside depends on that fragile ecosystem, the soil. Rothamsted's early reputation owed much to its work on soils so, appropriately, the Station's ongoing work on soil fertility and pollution is outlined in this general report as a background to some of the more recently-developed areas of interest.

Changing soil fertility with time. Many of the products which satisfy our creature comforts are produced in factories which, if destroyed, can be rebuilt and returned to full production within months or years. Not so the soil which produces the food to sustain us. Soil is a vastly complex medium that has taken many tens of thousands of years to develop. Whilst we can measure the amounts of the different sized particles of sand, silt and clay in soil, it is the way these are aggregated to leave voids for air and water that is important. Living organisms within soil can be estimated; within the top 25 cm of an ordinary arable soil there exist many organisms—fungi, bacteria, invertebrate animals, as well as roots—equivalent in weight to 100 sheep per hectare of land surface. The quantity of plant nutrients and water can be determined and an estimate of their availability made. In very complex ways all these factors interact to make the soil fertile, and thereby able to produce wholesome food. The dire consequences of the loss of soil fertility has been highlighted by the tragedy of recurrent famine in Africa.

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In past reports we have described the effects of agricultural practice on the soil and have also shown how man's non-farming activities may have even more damaging effects. Last year we highlighted problems of heavy metal contamination on soil microbial processes and possible effects that afforestation with broadleaved species of tree could have on soil acidification. In this report we describe in some detail work related to the release of nitrate from soil organic matter and the risk of loss of this nitrate by leaching.

Rothamsted has a unique collection of crop and soil samples from the Classical Experiments since these were started by Lawes and Gilbert in the 1840s and 1850s. These experiments continue on their original large plots and all have a control or untreated soil against which to compare the effects of standard farming treatments like fertilizer applications. In a collaborative programme with colleagues at the University of Lancaster some of these soils and crops have been analysed recently for their contents of cadmium and polyaromatic hydrocarbons (PAHs) now that there are analytical techniques capable of doing this. PAHs are a group of environmental contaminants, many of which are known to be mutagenic and carcinogenic. They are formed during combustion and produced naturally from the burning of vegetation. However, combustion of fossil fuels and other anthropogenic processes such as waste incineration have greatly increased the quantity of these compounds. Man is exposed to their effects mainly through ingestion of food. Our results show that in soils which have grown cereals or grass since the 1840s, the cadmium and PAH content has increased, cadmium since the 1940s, and PAHs since the 1950s, irrespective of whether or not they have received fertilizers or other man-made additives. The increases are due entirely to man's non-farming activities. In this case the population at large, and not the farmer, is contributing to the serious possibility of a decline in the fertility of our soils. Whilst cadmium inputs may well decline in response to the control of emissions from point sources, PAHs, which enter the atmosphere from the low temperature combustion of organic materials, are probably coming from many diffuse sources. Our results suggest a need to monitor carefully such inputs and seek control measures.

Biotechnology

Diagnostic methods for plant pathogens and pests. Those working with viruses have long been familiar with the use of immunological methods for their diagnosis but the development of monoclonal antibodies, which allow the identification of specific organisms, and simple tests based on a colour reaction, such as enzyme-linked immunosorbent assay (ELISA), have extended the use of such methods enormously. Immunological tests now have the potential to be used by farmers or advisers to identify many pests and diseases easily and quickly, thus improving prospects for control.

For example, a new technique has been developed for the rapid and sensitive detection of potato virus Y and potato leafroll virus in potato leaves and tubers. It utilizes a soluble dye and thus avoids the complications of colour from plant sap and can be assayed visually in simple laboratories or 'on the farm'. Tests for the detection of pea seed-borne mosaic virus by ELISA have been improved, and monoclonal antibodies have been used to define more precisely strains of barley yellow dwarf virus. The specificity of polyclonal antisera to the Sumatra disease bacterium (SDB) of cloves and to *Pseudomonas solanacearum*, a serious bacterial pathogen in the tropics, was improved to enable discrimination between SDB and *Ps. solanacearum* using ELISA; this has not been previously achieved. The future will see an expansion in, and application of, such methods across a still wider range of plant pathogens.

Similarly, progressively more pests, difficult to identify by conventional means using morphological characters, can be distinguised by molecular biology techniques. The potato cyst nematodes (PCN), *Globodera rostochiensis* and *G. pallida* are major pests of potatoes throughout the world. In the UK alone they can claim between 2 and 9% of the national

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crop, a cost equivalent of approximatelty £50 million. Effective control depends on accurate and reliable identification of these species and their pathotypes, so a novel and potentially powerful method of characterizing PCN has been devised. Restriction endonuclease enzymes recognize specific nucleic acid sequences and cleave the DNA at these or adjacent sites. The DNA fragments thus derived from repetitive DNA can be used to distinguish between different PCN populations. Unfortunately such highly repetitive fragments represent only a small proportion of the total genetic material in each cell. To use the much less frequent fragments for identification they must be cloned, giving them great potential as sensitive identification probes. A library of DNA fragments has been produced from *G. pallida*, and two DNA probes that differentiate *G. pallida* from *G. rostochiensis* have been isolated. Modification of the detection methods could lead to the production and wide use of small laboratory- or field-based kits for identifying nematodes rapidly and easily.

Improving crop plants. If novel genes are to be introduced into crop plants, it is essential that they should be expressed only in the correct tissue and at the required time. For example, genes for wheat gluten proteins should only be expressed in the endosperm of the developing grain. We have recently identified the specific regions of barley seed protein (hordein) and potato tuber protein (patatin) genes that determine this specific expression. These regulatory sequences are adjacent to those that encode the proteins. The identification was made by fusing the regulatory sequences to a bacterial sequence encoding a readily assayed enzyme, and introducing the resulting chimaeric genes into potatoes (patatin) or tobacco (hordein) using standard transformation procedures. The patatin regulatory sequence resulted in synthesis in the endosperm but not the embryo of the developing tobacco seeds.

Another exciting achievement foreshadowed in last year's Report has been to introduce resistances to potato leafroll virus and potato virus Y into potato germplasm by fusing protoplasts of dihaploid lines of cultivated potato with those of a sexually incompatible wild South American species, *Solanum brevidens*. The hybrids proved to be female fertile and can be crossed with cultivated potatoes. Field studies of the hybrids, which are classed as 'genetically manipulated', were made under the guidelines laid down by the Advisory Committee for Genetic Manipulation. This work shows that the combination of potato genomes by somatic hybridization could play an important role in potato breeding, especially in providing a bridge between sexually incompatible material.

Safety of genetic manipulation. Currently there is great debate about whether organisms should be genetically manipulated and even greater controversy about whether it is safe to release such organisms from the laboratory into the environment. Certainly little is known about the degree of risk associated with gene transfer between introduced organisms and the native soil population. After much discussion the Advisory Committee for Genetic Manipulation, the relevant Committee of the Health and Safety Executive, decided that they had no objection to Rothamsted conducting a very simple experiment to try to assess the risk of gene transfer.

This experiment is being done in co-operation with other laboratories in Europe. *Rhizobium*, a benign, ubiquitous soil bacteria about which much is known, was chosen because it is the organism which produces the nodules on leguminous plants. It is therefore easy to recover from soil via the nodules when legume roots are carefully collected. Strains of some of these bacteria exist in which mutation has given rise to resistance to certain antibiotics. Into such a strain it was possible to insert as a marker a gene sequence which confers resistance to other antibiotics. This 'marking' mechanism will show whether genes introduced into released organisms subsequently spread in the field and, in that eventuality, the implications for the release of other, more radically engineered organisms that are being developed.

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Legume inoculation. Whatever 'new' organisms or systems are in future devised in the laboratory, to be of any use they must be usable in the field, and frequently this will require special packaging or formulation to derive maximum benefit. One such example is the inoculation of grain legumes with *Rhizobium,* large numbers of which must be applied to the seed or soil at planting. Techniques for both on-farm and commercial inoculation have been used but neither has ensured optimum nodulation, the former requiring seed to be sown almost immediately post-inoculation, and the latter providing inadequate *Rhizobium* numbers and/or poor shelf life. On-farm systems involve mixing dry or moistened seed with peat-based inoculants immediately before sowing but weak adherence to seed and poor rhizobial survival are major drawbacks. Commercial inoculation often involves a high temperature drying phase that lessens the number of viable cells.

One way of circumventing some of these problems, particularly if the seed is dressed with agrochemicals toxic to *Rhizobium,* is to apply the inoculant directly to the soil in a granular form. Formulations and granulation methods have now been developed that provide free-flowing granules containing $>10^8$ viable *Rhizobium* cells per gram and shelf-life of at least seven months.

An alternative strategy is to develop inoculants containing dessication protectants and application methods which will reduce mortality during application to seeds. Mixtures of peat, clay and various adhesives that protect *Rhizobium* during drying, combined with a low temperature coating method have proved satisfactory for pre-inoculated seed. The method gives between 10^3 and 10^5 viable *Rhizobium* per seed, depending on seed size and the pre-inoculated seed has a shelf-life of more than three months. The methodology involved is simple and requires no expensive seed coating machinery. With simple modifications the method can be used on-farm, giving farmers the opportunity to inoculate seed several weeks or even months prior to sowing.

Patent applications have been filed by the Agricultural Genetics Company Limited to cover the incorporation of the protectant into peat-based inoculants, the granulation method and the cool temperature coating method used to produce the pre-inoculated seed.

Presentation of chemicals for insect control. Similarly, the effectiveness of some novel insect control agents is greatly dependent on their formulation. The various types of semiochemicals now being developed for pest control need to be presented to pests in ways very different from those used for conventional toxicants. For example, antifeedants must be applied uniformly to plant surfaces and formulated so that their biological effect is long-lasting, whereas alarm pheromones need to be applied as quick release formulations that produce a rapid change in the concentration of the active ingredient as a vapour. Methods have been developed to achieve these widely different requirements.

Statistical computing

It is a pleasure to report that Genstat 5 has now been released commercially by the Numerical Algorithms Group. This new version is significantly different from previous versions, which had begun to seem old-fashioned when used on the faster, interactive computers and workstations that are now available. There are many types of analysis where the scientist or statistician works best by using an interactive programme to build the analysis step by step, examining the results of each stage before deciding what to do next; examples are in sequential model fitting and data scrutiny. There is still, of course, a need for batch working, particularly for routine analyses, and Genstat 5 allows for this. However, interactive work has now been made much more convenient by a new syntax and by redesigned output. The new syntax is also more consistent, making it easier to learn and remember. New facilities include high quality computer graphics, the randomization of generally-balanced designs and

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facilities for fitting a range of standard growth and exponential curves. There is also a procedure structure, which can be used to store complicated analyses and make them easily accessible to those without detailed technical knowledge. We anticipate that all this will make Genstat 5 much more accessible to non-statisticians and those without training in computing.

The released version is the culmination of several years' work. Before programming began in 1984, a year was spent in detailed planning and in checking the ideas. The first test version was prepared in August 1985 for demonstration at the Genstat conference at York. This was incomplete, but further development and testing took place at Rothamsted during 1985 and early 1986, after which versions were made available for use (and for field testing) at other VAX sites in the AFRC, as well as a few elsewhere. It is a great advantage for Genstat that we have such a strong user community in our own organization. This has enabled us to assess the facilities locally (and several minor changes have been made in response to users' comments); also the extensive field testing with many different styles of use has made it possible to find and correct many of the problems that arise only in unusual circumstances. While the field testing was going on, the *Genstat 5 reference manual* was being written (767 pages), and this has now been published by Oxford University Press. The book *An introduction to Genstat* has been revised, to become *Genstat 5: an introduction*, and will also be published by Oxford University Press early in 1988.

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