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Rothamsted Experimental Station Report for 1984

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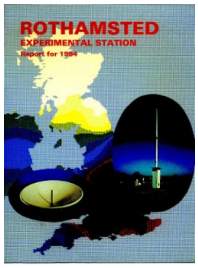

General Report

Rothamsted Research

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GENERAL REPORT

This 1984 Report is written against a background of major changes in the agricultural scene. National yields of cereals, particularly winter wheat and barley, attained levels 20–25% higher than any recorded previously, whilst quotas were imposed under EEC regulations on an otherwise highly buoyant milk production sector. Certainly, research has been highly successful in providing the agricultural industry and the practical farmer with new knowledge and technology, and the emerging new methods and materials have been adopted and exploited very perceptively, and with great effect. Yet sadly, these very successes have coincided this year with significant reductions in research funding, and researchers may be deemed to have been too successful for their own well-being. Statements made late in the year by members of government and by national farmers organizations presented future policy options in which the need was recognized for agricultural practices that would maintain low commodity prices, enhance the quality of produce, and show greater sympathy for environmental considerations; the goal of maximum production no longer was considered paramount.

Lawes Agricultural Trust Committee. Mr J. S. Martin, CBE, who had been a representative of the Royal Agricultural Society of England (RASE) on the Committee since 1981, resigned following his appointment to the new Priorities Board advising the Ministry of Agriculture, Fisheries and Food (MAFF). He had brought to the Committee's deliberations an expert and highly valued knowledge of arable farming, and had acted as Treasurer for the last two years. Mr A. F. Pemberton, an arable specialist farming near Cambridge and a member of Council of RASE, was appointed to the vacancy, whilst The Earl Ferrers accepted the office of Treasurer.

Staff. J. A. Nelder retired from the Headship of the Biomathematics Division at the end of October. He joined Rothamsted in 1968 as Head of the Statistics Department, and under his leadership the Station maintained its traditional high esteem in this discipline. He received world-wide recognition as the creator of Genstat and several allied computer-based statistical programmes, that have been licensed in many versions to users at numerous centres at home and overseas, and late in the year he gained an Inventor's Award for these highly original and successful developments. J. C. Gower succeeded him as Head of Division. M. Elliott, the leader of the synthetic pyrethroid group, retired officially from his unified grade 5 (DCSO) post in September, but is remaining for some time as a Visiting Scientist in the Insecticides and Fungicides Department with sponsorship from the British Technology Group (BTG). Two Heads of Department left the Station. Following the termination of work in the Molecular Structures Department in September, Mary R. Truter was seconded to University College London for the concluding months of her service: she has held an honorary appointment as Visiting Professor at the College for many years, and expects to continue her scientific interests at this new location. J. E. Beringer, who had been Head of the Soil Microbiology Department for four years, moved to the University of Bristol in April as Director of the Unit of Molecular Genetics.

Others who have retired from or left the staff of Rothamsted after long periods of service include: Margaret E. Brown (Soil Microbiology, 28), Sybil A. Clark (Nematology, 30), Elsie Davies (Statistics, 23), B. K. French (Physiology and Environmental Physics, 25), D. N. Greet (Nematology, 36), G. D. Heathcote (Broom's Barn, 32), Myrtle E. Hughes (Field Experiments, 44), K. Huntington (Engineering and Maintenance Services, 23), R. A. Jarvis (Soil Survey, 28), G. H. King (Plant Pathology, 33), I. Macfarlane (Plant Pathology, 37), W. N. Moore (Broom's Barn, 46), A. C. D. Newman

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(Soils and Plant Nutrition, 28), F. T. Phillips (Insecticides and Fungicides, 24), Heather Pellant (Physiology and Environmental Physics, 45), R. S. Seale (Soil Survey, 37), and L. R. Taylor (Entomology, 37); parentheses show individual's final department and years of service.

Honour. D. Mackney was made an Officer of the Order of the British Empire in the New Year Honours list, 1985.

Buildings. The construction of a Conference Centre commenced in August. The building will accommodate 250 people, yet its design will provide a convenient venue for smaller gatherings. Thus for the first time in the Station's long history, we shall possess a purpose-built meetings centre. Sir John Russell as Director in 1930 attempted to raise outside funding to erect a Conference Hall, but at that time of economic depression the appeal was not successful. During the past two or three years, the Station's management has been very active in raising funds to augment monies provided by the Lawes Agricultural Trust (LAT) and the Agricultural and Food Research Council (AFRC), such that almost £400,000 has been received from major Foundations and Charities, from industrial companies engaged in agriculture or food, and from the Station's suppliers and other well-wishers. A full list of donors will be recorded in the building, after its expected completion late in 1985. The widespread and generous support given to this appeal in a period of general financial constraint is most gratifying, and demonstates the confidence of our supporters in Rothamsted's present and future research activity.

A second major building scheme to replace an old range of glasshouses used by soil scientists, plant nutritionists, soil microbiologists and crop physiologists began in mid-summer and should be completed early in 1985. The new series of houses will be computer-controlled, and the associated header houses are being redesigned and modernized.

These two developments are occurring at the centre of the laboratory site and with adjacent landscaping, should improve markedly a visitor's initial impression of the campus.

The research programme: reduced finance and consequent change

Last year's Report commented on several high-level reports relating to the organization and funding of the nation's agricultural research activities, and outlined a series of decisions reached by AFRC in regard to the restructuring of arable crops research. In consequence, experimental work in Rothamsted's Molecular Structures Department ended in September. Another aspect of this reorganization involved the amalgamation of the AFRC Letcombe Laboratory with Rothamsted, with ultimate closure of the Letcombe site. (A group of Letcombe's plant physiologists will transfer to Long Ashton Research Station.) The laboratories at Letcombe are expected to close at the end of March 1985, but certain important off-site field experiments will be continued, some until 1988. Plans for the future combined programme have been developed within the confines of an overall budget reduced in real terms by almost 25% over the three-year period (1984–1987). It is intended that the main themes of Letcombe's work will be continued (see the introduction to the Soils Division report, p. 170). Twenty-four posts, some as vacancies, will be transferred from the Letcombe to the Rothamsted complement to meet the staffing needs of the projected programme; of these staff, three or four will remain in the Letcombe area to service, in a full-time capacity, the continuing major off-site field experiments.

Many individual scientists holding posts at Letcombe left during the year having found alternative posts within the Agricultural and Food Research Service (AFRS), or with

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other employers; others have retired early. The losses have reduced greatly the need for compulsory redundancies and, in conjunction with retirements from Rothamsted, they have allowed the immediate level of savings required in work on crop production within the joint Rothamsted-Letcombe programme to be met.

The restructuring exercise also called for a considerable curtailment of support for crop protection work directed towards arable crops, and this requirement for retrenchment has affected Rothamsted seriously. On present plans more than a quarter of the scientific posts forming the Crop Protection Division at its inception in August 1983 will be lost before March 1987: 25 posts were declared redundant in September, and a slightly larger number of posts will disappear as staff retire normally or prematurely, or leave at the end of fixed-term contracts. The impact of these reductions on the research programme is described in the introduction to the Crop Protection Division report (p. 91); whilst the losses are serious, the Station will seek to maintain a balanced and relevant programme in crop protection whilst emphasizing innovative investigations of high scientific quality.

The resulting difficulties of operating research have been compounded by two further downward adjustments of indicated future budgets conveyed by AFRC to Institutes in the last months of the year. These successive adverse changes in financial support erode and divert the time available to senior scientific managers for creative thinking and research planning, reduce flexibility in the use of resources, and damage the motivation of staff, whose morale is already lowered by uncertainties surrounding job security and the operation of the AFRC Redundancy Agreement.

Funds available for the purchase of capital laboratory equipment have fallen sharply, and the replacement of several obsolete major items has not been possible this year: the pessimistic indication of money likely to be available for this purpose in the next two years causes great concern, because the effectiveness of our scientists must diminish if this situation is prolonged, and their ability to be truly competitive in scientific innovation and discovery will be threatened.

Promoting scientific achievement and understanding

This Report and the several hundred papers appearing annually in the scientific literature form the main documentation of Rothamsted's scientific progress. However, our appeal for funds for the Conference Centre simultaneously promoted an understanding of the Station's role and programmes in agricultural research to a wide spectrum of industrial organizations, and more generally to the agricultural industry, and its suppliers and customers, both nationally and internationally. These efforts have been supplemented by other Rothamsted activities designed to disseminate research information through the medium of the 'Friends of Rothamsted', by Subject Days, and by participation at national agricultural events.

Friends of Rothamsted. This organization formed in summer 1983 consists mainly of leading arable farmers, supplemented by a small number of advisers and consultants. It has become a principal focus through which our applied research findings are transmitted to practical users, but also provides an enthusiastic group at the sharp-end of farming capable of appreciating possible new opportunities arising from innovative projects. The Friends normally hold well-attended summer and winter meetings at the Station, and membership of the organization is still open to interested individuals.

Subject Days were held in November, this year's theme being 'Biotechnology: manipulating organisms for agriculture'. The presentation attracted about 150 visitors on each of two days, and provided an excellent opportunity for scientists from the universities, industry, and other government-funded laboratories to exhange information

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and ideas in the rapidly advancing fields of plant molecular biology and genetic engineering, and in the use of biological inocula to improve crop nutrition or the control of crop pests.

Other events. The Station participated in five exhibitions or demonstrations organized by the RASE. The 'Barley '84' event held on a site near Northallerton formed a major farming occasion, and included both field and indoor demonstrations: outdoors, Rothamsted scientists demonstrated the Station's multifactorial approach to determining the factors affecting the yield and quality of the winter barley crop. Our contribution to an AFRC-sponsored indoor exhibit presented information on seed proteins for cultivar identification, biochemical markers in plant breeding, strategies to combat fungicide resistance, cereal cyst nematodes and intensive cereal production, the biological control of cereal cyst nematodes, the control of barley pests particularly stem borers, and the influence of N fertilizers on both yield and nitrogen content of grain. The other events were held at the National Agricultural Centre, Stoneleigh. The most important was the Royal Show held in early July, when the Soil Survey of England and Wales exhibited the completed 1:250,000 National Soil Map, and when entomologists demonstrated the Rothamsted Insect Survey system and the unique opportunitites provided by radar techniques for enhancing information concerning pest aphid migrations and damage prediction: the other NAC events to which Rothamsted contributed were directed to potatoes, grassland, and farm electronics.

Members of the Soil Microbiology Department joined with collaborators from the Grassland Research Institute in presenting an exhibit on the measurement and control of biological nitrogen fixation in legume root nodules at the Royal Society's Soirées in May and June.

Visitors included, at Government level, Lord Belstead, Minister of State (Lords) at MAFF, the Hon Mr Peter Brooke, MP, Under-Secretary of State at the Department of Education and Science (DES), and Mr Qian Chuanbing, Scientific Counsellor at the London Embassy of the People's Republic of China. Senior scientific visitors were welcomed from many countries: Dr H. Geissbühler, Director of Research of Ciba-Geigy, Basle, reviewed opportunties for research collaboration in the fields of molecular biology and biological control, and Dr B. Györffy, Director of the Martonvásár Agricultural Research Institute, Hungary, had detailed discussions on cereal production. Parties of students, farmers, consultants and agricultural merchants supplemented individual visitors. Sixty-five overseas scientists from 30 countries were attached to research departments during the year, and the Station provided supervisors for a corps of Ph.D. and sandwich students: these associations have created new, or reinforced existing relationships with research centres at home and abroad.

Overseas visits by Rothamsted staff. As a matter of policy, even in the present phase of financial retrenchment, the Station has striven to maintain an active programme of overseas visits, made possible in large measure by the generosity of a wide range of external sponsors. Overseas visits by staff provide opportunities for the dissemination of the latest research findings arising from our programmes to international gatherings of scientists or to smaller local groups: they also ensure that our scientists remain keenly aware of developments in appropriate fields of science. The Station was represented strongly at major discipline conferences in computing/statistics (Compstat '84, Prague), entomology (XVII International Congress of Entomology, Hamburg), and soil hydrology (International Soil Science Society, Wageningen). Collaboration with agricultural research in France has been maintained by visits to laboratories of the Institut National de

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la Recherche Agronomique (INRA) to exchange information on soil hydrology and cereal seed proteins. Soil microbiologists concerned with improving symbiotic nitrogen fixation have participated in national meetings or research programmes in Australia, Bangladesh, Kenya and Turkey, whilst P. B. Tinker was invited to visit centres of soil science research in China and Malaysia. S. W. J. Bright attended the International Conference on Plant Tissue Culture held in Beijing, and visited several major cities in China where laboratories are engaged in such work.

Weather and crops

The growing season for 1984-harvested crops generally was most favourable. Winter cereals had been planted in autumn 1983 in line with experimental schedules, and crops established and developed well in the last months of the year. Leaf area indices attained by December were often unusually high, and this feature allowed the crops to intercept higher than normal proportions of solar radiation in early spring and to progress well. Average ambient temperatures during the phase of grain filling were also favourable, with the result that mean grain weight often was increased by 20–25% in comparison with values determined in recent years. At Rothamsted, the conditions for sowing of spring cereals were also generally good, and no serious problems occurred in the later growth of these crops. A relatively dry period during July and August allowed harvesting to proceed smoothly. Some exceptionally high yields were obtained: with winter wheat, several individual plots gave more than 12 t ha^{-1}, and some field yields exceeded 10 t ha^{-1}; the area sown to barleys was less than usual, but again yields were very good, with occasional plots yielding in excess of 10 t ha^{-1}. In its last year on the Broadbalk continuous winter wheat experiment, the cultivar Flanders also produced some exceptionally good yields; Brimstone has replaced Flanders on Broadbalk this autumn, and the mineral nutrient treatment of two plots of the experiment has been modified to test higher levels of fertilizer–N (240 and 288 kg N ha^{-1}). The area planted to potatoes was similar in 1983 and 1984, but the conditions for planting the 1984 crop were much better. Later growth was good, and the rather dry period in July and August appeared not to affect yields unduly. Lifting of the crop was sometimes difficult due to heavier than usual autumn rainfall, but good experimental plot and field yields were recorded.

Autumn planting of the 1985 crops of winter wheat, barley and field beans was affected by the high incidence of wet days and associated poor drilling conditions, and some adjustments to plans for experiments testing sowing dates as a factor were necessary. The harvesting of sugar beet at Broom's Barn, and more generally in the growing regions also suffered interruptions caused by difficult autumn field conditions, but overall it has been an exceedingly good year for sugar yields: as early as June, observations on the growth of the crop at Broom's Barn had indicated that it would yield more heavily than in 1983, and the eventual national average yield, 7.4 t sugar ha^{-1}, was the second highest ever recorded.

The multidisciplinary field experiments

A detailed report on the 1984 results of these important experiments begins on p. 23. The series of experiments commenced nine years ago as a response to the increased realization that whilst a multiplicity of factors, often interactive in nature, affected the yield of crops, there were unique opportunities for favourably manipulating these factors providing a broad understanding of the relevant scientific background could be gained by a multidisciplinary approach. Project teams were assembled for work on particular crops, members usually being drawn from several disciplines. The comprehensive design of the experiments, and the results gained to date have attracted the interest of scientists and

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farmers alike. The initial series of multifactorial experiments on winter wheat and spring beans ended with the 1984 harvests. Both had achieved most of their aims, aiding understanding of factors limiting yield and how they interrelate; and both have uncovered some problems requiring a more specialized scientific approach. New teams have commenced similar multifactorial experiments on oilseed rape and straw disposal: in this way the scientific resources of the Station are used flexibly to investigate demanding or emerging problems.

Science in agriculture: new directions and opportunities

In recent years agriculture in the United Kingdom has been outstandingly successful when judged by any usual criteria, especially those of satisfying national sufficiency and of high production per capita of the workforce. This commendable situation has been attained by the intelligent and purposeful application of the findings of research by UK farmers, who have demonstrated a willingness to test and adopt new practices appropriate to their particular farming operations. In the arable sector, the remarkable rise in both the standards of farming and of crop yields may be attributed to a steady flow of improved varieties of higher potential performance, the adoption of better and more timely soil cultivation practices, the increased understanding of how environmental factors affect crop growth and the attempts to harmonize agronomic practices with external conditions, including a steadily increasing supply of N fertilizers, and an ability to provide better protection for crops against competing weeds, pests and diseases. This national success story based on an effective partnership between research scientists, advisers and farmers, and encouraged especially in the cereals sector by the financial arrangements of the EEC's Common Agricultural Policy, has been tempered by the mounting concern, expressed by politicians and public, for the impact modern agriculture is having on the countryside and on man's environment more generally. There have been many calls recently for the adoption of agricultural practices that show a greater sympathy for the environment, and research must recognize and increasingly react to this situation. This section of the Report draws attention to projects within the Rothamsted programme that are highly relevant to environmental issues; it also introduces briefly some new projects funded under the AFRC's new initiatives scheme to foster foward-looking speculative research that, if successful, may markedly change future directions or opportunities in crop production.

Research interfacing agriculture and the environment

Royal Commissions reporting during the last five years have assessed the extent to which agricultural practices may adversely affect the human environment as reflected in the quality and purity of food and drinking water, in the visual aspects of the countryside, and in the general pollution of the aerial environment by chemicals, smoke or unpleasant odours. Four agricultural practices were identified as of greatest concern: the use of nitrogen fertilizers and the possible consequential build-up of nitrate in drinking water; the level of pesticide use in current crop protection systems; the intensive rearing of farm animals resulting in excessive localized slurry production; and the burning of straw after cereal harvesting. The Rothamsted programme includes studies appertaining to each of these areas of concern: several of these are well established and already have provided much information of value in devising better strategies and practices, others are now beginning or just producing the first useful results. Our wide involvement and success in research examining the interface between agriculture and the environment was recognized by the House of Lords' Select Committee which reported in Summer 1984 that members were 'much impressed by the work they saw at AFRC's Rothamsted

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Experimental Station; an active pursuit of environmental projects was evident among the agricultural scientists there'. The following paragraphs highlight some of this research.

Predicting nitrogen requirements. Farmers do not wish knowingly to overspend on their inputs, and so are anxious to know how much nitrogen to apply to crops growing on various soil types, particularly in spring after different patterns of winter weather. At present, the amount of nitrogen applied is determined using tables drawn up on the basis of results from numerous field experiments. We aim to devise a less empirical system for predicting N requirement, that will improve the match between fertilizer application and crop need, thereby attaining the desired yields with the minimum use of fertilizer. On the basis of field experiments over the last four years, a model has been constructed to predict mineral nitrogen in soil in spring, and hence fertilizer need. This has now been tested successfully in a series of trials carried out by ADAS. A longer-term model has been developed to predict how a pulse of ^{15}N moves through the soil-plant system over several years.

Biological fixation to spare fertilizer-N need. The inoculation of legume crops with rhizobia strains has a long history, but until recently most inoculant preparations have proved unreliable in practice. Soil microbiologists at Rothamsted have wide experience in the recognition and handling of strains of *Rhizobium,* and this accumulated knowledge has been used to advise New Plant Products Ltd, a small group within the Agricultural Genetics Company based on our campus, on satisfactory methods for producing inocula for soya bean, lucerne and white clover. In 1984, production rose to about 20,000 units, the majority being exported to southern Europe. In field experiments in the UK, inoculation with selected strains of *Rhizobium phaseoli* has given significant increases in the yield of navy beans, and French bean pods, grown without N fertilizers. Inoculation, together with a small amount of N fertilizer (30–50 kg N ha^{-1}), gave yields similar to those obtained following standard UK farm practice in which N is given at 100–150 kg ha^{-1} at sowing and 40–60 kg ha^{-1} at flowering. Most *Phaseolus vulgaris* seed sown in the UK is dressed with a fungicide (captan), which is toxic to *R. phaseoli*, rendering slurry inoculation ineffective. However, liquid preparations, sprayed into the planting furrow, or granular inoculants combine-drilled with seed have proved effective. We are developing long shelf-life granular inoculants that should be available to growers soon.

Straw disposal. As a response to the considerable adverse publicity on the practice of straw burning following the 1983 cereal harvest, the AFRC decided to coordinate the various programmes on straw disposal at its Research Institutes. P. B. Tinker, Head of Soils Division, was invited to act as Coordinator and be Chairman of a Management and an Operations Group. R. D. Prew, Field Experiments Section, was appointed as Technical Secretary to both. The Operations Group, composed of scientists from six institutes, together with a representative from ADAS, have assessed current work and identified areas where additional effort is required immediately, especially with regard to straw incorporation.

At the same time Rothamsted has joined with the National Farmers' Union to launch a Straw Incorporation Register to include farmers who are incorporating straw. It is intended to build up a fund of information on both problems and successes, find logical explanations for these and so help to spread successful methods and guide research and development. A questionnaire has been circulated to determine farmers' 1983–84 experiences, and the replies will be analysed by the Statistics Department.

These developments seeking viable alternatives to straw burning will enable new work

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at Rothamsted on options for straw disposal to benefit from general farmer experience and from much good previous research conducted at the AFRC Letcombe Laboratory.

Reduction of the pesticide burden on the environment. The introduction to the Crop Protection Division's report exemplifies much Rothamsted work on this general theme: opportunities for minimizing pesticide use are sought by advancing and disseminating the findings of research concerned with improved monitoring and forecasting methods for crop pests and diseases, modifications of cultural practices, biological control agents, and new and novel chemicals, both synthetic and naturally-occurring, showing greater inherent biological activity and safety. Chemical work in the Insecticides and Fungicides Department has gained high international esteem by development of the series of highly successful and safe pyrethroid insecticides. But, as with most classes of insecticides, resistance has been encountered in some pest insects, especially in situations where the application of the chemicals has been relatively unenlightened. However, studies concerned with the spread of resistance genes within natural populations of insects have proceeded well, and suggest that strategies can be devised for the use of pesticides in ways less likely to induce the development of high levels of resistance. Meanwhile, two new chemical developments, the production of insecticidally-active non-ester pyrethroids and lipophilic amides, provide new leads for possible future insecticide production.

Fungal pathogens, like insects, can develop resistance (or tolerance) to fungicides. At present, a study is being conducted of resistance development and fitness in field populations of the eyespot fungus *(Pseudocercosporella herpotrichoides)* on wheat. The findings should enable us to model disease spread and to devise strategies for fungicide use leading to more efficient control, or indeed to decreased applications, practices that in turn will diminish the risk of further foci of resistance developing.

As with fertilizers, farmers would like to reduce the cost of their pesticide inputs, but they need an assurance that lower and/or less frequent pesticide applications can be accommodated without any significant reduction in pest or disease control. Much of our monitoring and forecasting work seeks to provide the knowledge base for such assurances. The scheme for predicting likely damage caused by the pea moth, based on a monitoring scheme employing pheromone-baited traps, has been highly successful in the UK during the last five years and has led to improved control with less pesticide. New work to develop pheromonal monitoring systems for two more pests, pea midge and oilseed rape pod midge, has commenced and progress in the first season has been good. Light traps operated from Rothamsted have been used to survey moth populations throughout much of Britain since 1933, and records are continuous since 1960. The data complements that gained for aphids from suction traps, but it also provides unique information enabling an analysis to be made of the manner in which long-term changes in moth populations relate to, and are influenced by, environmental factors, including changes in agricultural practice, and possibly pesticide use. Data available from the aphid suction traps contributes to the scheme forecasting the likely incidence of barley yellow dwarf virus (BYDV) on autumn-sown cereals. This virus is spread in the autumn mainly by the aphid, *Rhopalosiphum padi,* and the likelihood of BYDV on particular crops may be gauged using an index combining knowledge of the migrant populations of *R. padi*, the proportion of the insects carrying the virus, and the date of autumn-sowing of the cereal (the earliest sown crops are the most prone to infection and consequent damage). It is possible in some seasons and situations to assure farmers that BYDV damage will be negligible, and that an autumn insecticide spray would be uneconomic, and therefore should not be applied.

Other innovative approaches to crop protection involve assessments of natural products such as aphid alarm pheromones, repellants or anti-feedants of plants, and plant

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products exhibiting fungicide activity. The aphid alarm pheromone, (*E*)-*β*-farnesene, used in conjunction with a synthetic pyrethroid, enhances contact between the aphid and the foliar-applied insecticide by increasing insect movement, and results in a higher percentage kill from a given dose rate. Formulations suitable for applicaton using electrostatically charged, rotary atomizers may further enhance the efficacy of pesticide usage. A natural product of the marsh pepper plant, polygodial, acts as a strong deterrent to aphids, and its presence in the atmosphere surrounding crop foliages reduces feeding activity. The compound if available in reasonable quantity, either following extraction or by stereospecific synthesis and/or resolution of the natural isomer (other isomers are phytotoxic), could become another valuable tool for controlling the spread of viruses by aphids – and, more speculatively, it may be possible ultimately to transfer the genes specific for polygodial production from marsh pepper into the major arable species, and so confer an in-built antifeedant property. In like manner, glucosinolates naturally present in brassicas confer tolerance to a range of fungal pathogens, but tolerance is less marked in cultivars low in glucosinolates. The anti-fungal activity probably resides in isothiocyanate products formed enzymically from the glucosinolates, and although isothiocyanates are fungitoxic *in vitro*, they are normally too volatile and unstable for field use. Now a novel way of stabilizing these compounds to yield slow-release formulations has been developed; these formulations, when applied using the Rothamsted APE 80 electrostatic rotary atomizer, provide good control of fungal pathogens and may be used in lieu of benomyl to protect low-glucosinolate oilseed rape cultivars.

Farm organic wastes cause localized, but unacceptable environmental pollution, yet few feasible approaches for containing and reducing the problem have emerged. Against this daunting situation research in the Entomology Department has shown that earthworms can process this waste material very successfully into valuable horticultural/agricultural composts whilst the worms simultaneously constitute a nutritious feed protein. The process has been licensed through the BTG to British Earthworm Technology, and this company has continued to expand and exploit the Rothamsted initiative. The potential of this vermiculture process to lessen pollution was recognized by Rothamsted's inclusion among the first four recipients of the Pollution Abatement Award sponsored by the Environment Risk Analysis System Foundation in association with the Confederation of British Industry, the Department of Industry, and the Royal Society of Arts.

New initiatives in molecular biology

Techniques of molecular biology, particularly those using recombinant DNA, are proving extremely powerful in analysing and understanding a wide range of agricultural problems. Over the last six years the Station has developed considerable expertize in this area and initial results have proved sufficiently promising for us to make successful applications for New Initiatives Funds to expand work in three diverse areas.

Role of the component proteins of gluten. Gluten is the viscoelastic proteinaceous material left when starch and soluble proteins have been washed out of wheat bread dough. The quality of gluten greatly influences the quality of the dough and, in turn, the character of the gluten is dependent on the nature of its protein components. These are highly complex, polymorphic series of proteins and only a limited amount of information about their structures can be obtained using conventional techniques of protein chemistry. The new approach rests on the ability to isolate in pure form and sequence recombinant DNA molecules containing the coding information for the individual

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polypeptide chains and so to deduce protein sequences relatively rapidly. Advances in computer prediction of protein secondary structures from primary sequences then will be used to suggest structures for these molecules. The proposed structures finally can be confirmed using combined physical and chemical techniques applied to partially purified fractions or to complex mixtures. The project is being undertaken in conjunction with the AFRC Food Research Institute, Norwich. Some of the initial findings are reported in the Molecular Sciences Division report (p. 154).

Control of plant gene expression. All inorganic nitrogen assimilated by the plant is incorporated into the organic form via the action of the enzyme glutamine synthetase (GS). This exists in many different isoenzymic forms within the plant. Research, chiefly done by visiting workers within the Biochemistry Department, has shown that when a nodule develops on an inoculated root of *Phaseolus* a new form of GS increases rapidly in activity in concert with the formation of nitrogenase. Subsequently, cDNA clones have been identified which contain sequences related to nodule and root forms of GS. The results obtained confirm that the plant has a number (5–15) genes for GS; different members of this small multigene family are expressed in different organs. Apart from our intrinsic interest in this important enzyme, this gene family then provides a unique model system for investigating how plants control the organ-specific expression of genes. The New Initiative proposal, together with an AFRC Link Scheme with Dr J. V. Cullimore at the University of Warwick, will provide the necessary funds for a concerted effort to exploit this opportunity to understand metabolic regulation at the gene level.

Genetic basis of insecticide resistance. Earlier paragraphs have documented the serious threat posed to the success of chemical pest control by the development of resistance in insects to insecticides. A multidisciplinary study at Rothamsted has led to the identification of various biochemical mechanisms responsible for resistance. Peach-potato aphids, *Myzus persicae*, become resistant by producing increased amounts of an enzyme, carboxylesterase E4, that degrades and sequesters a range of insecticides. The most resistant aphid types produce 60–70 times as much E4 as susceptible insects, equivalent to approximately 1% of their total protein, but this ability may be lost in offspring of unselected clones. Although less detailed, other studies suggest that similar changes may be common in other insecticide-resistant insects. It is important, therefore, to understand not only the genetic mechanisms responsible for resistance, but also the processes involved in the spontaneous loss of resistance. This well-characterized situation in *M. persicae* presents a unique opportunity for such studies, and this year we have established that resistant aphids have more E4-specific mRNA. With the aid of additional staff made possible by New Initiative Funds, we shall extend the work on the molecular genetic basis of this resistance mechanism, expecting that the knowledge gained will suggest alternative opportunities for counteracting resistance.

A selection of other research activities

The foregoing sections have concentrated on topics of high current interest, but within Rothamsted's broad programme of research, progress has been achieved in many other areas. A few of these investigations are described briefly below.

Crop growth and the external environment. In the section on Weather and Crops, the ability to predict with considerable accuracy, several months before harvest, the yield of sugar from beet crops was mentioned. Prediction relies upon careful analyses of the effects of environmental conditions and agronomic treatments on the development of the leaf canopy, its interception of light and the rate of dry matter production by the crop.

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Nitrogen applications are beneficial during the early stages of crop growth because they promote the development of leaves, increasing size and longevity, but late applications are undesirable and lead to increased concentrations of non-sugar materials in the root. Effort is concentrated on defining the stage of crop development before which the last split nitrogen dressing is best applied.

The large and expensive mobile rain shelter at Rothamsted has allowed us to study the effects of drought on crop development over a period of years. However, this fixed facility enables these studies to proceed only on a single soil type (Batcombe series). A light, cheap and portable shelter, covering an area 18 m × 5 m, has been developed: it consists of a transparent plastic-covered tunnel supported on metal hoops fixed to a carriage running on a steel track. The shelter is driven by an electric motor and responds to a rain sensor. It is demountable, can be handled by two persons, and transported by lorry. This year it functioned successfully at Rothamsted and in future years will be used on a range of soils at outside sites to establish the ability of different soils to supply the water requirements of winter wheat and the effects of progressive drought stress on crop growth and yield.

Assessment of recently recognized viruses. In the 1982 Report, evidence was presented for the presence in oilseed rape of a luteovirus reacting in the ELISA test with antiserum to beet mild yellowing virus (BMYV). Studies of its host range characterized it as beet western yellow virus (BWYV), and a survey conducted in the spring of 1983 established its presence in 78 of 80 oilseed rape fields examined, usually in a high proportion of individual plants tested. The aphid, *Myzus persicae*, is the principal vector for BWYV, and field observations have shown that the aphid can overwinter on rape crops and develop large populations of alatae in the spring. In an experiment in which aphid populations were controlled with different aphicide treatments, various levels of virus infection were established and BWYV significantly decreased both seed yield and oil content. Therefore in years like 1983, when oilseed rape crops showed widespread infection with BWYV, considerable yield losses must have ensued. Fortunately, of five isolates of BWYV from rape, only two could be transmitted to sugar beet and even these to less than half the plants inoculated, so the danger of virus spread from rape to beet, though real, is probably only moderate.

Another virus, beet necrotic yellow vein virus (BNYVV) causes the very damaging disease, rhizomania, in sugar beet. The virus is transmitted by the soil-inhabiting fungus *Polymyxa betae*. Until very recently, the disease was considered to be important only in countries whose climate was warmer than that of the UK, but in 1983 its presence was established in the Netherlands. It must now be accepted that there is a real danger that it could become established in the beet areas of eastern England, and in consequence a major project was launched with the aims of studying the biology of the vector and minimizing the risks of importing infection. An initial survey has shown that *P. betae* is widespread in fields where beet is grown in England, but BNYVV has not been identified. This survey will be expanded, and selected roots from sugar beet grown in soils carrying *P. betae* will be screened carefully for any presence of the virus: a related study will examine the effect of cultural practices on the levels of *P. betae* in soils.

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