ROTHAMSTED RESEARCH

Rothamsted Experimental Station Report for 1986

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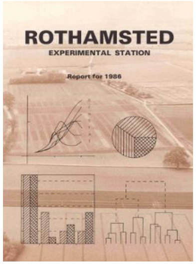

General Report

Rothamsted Research

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GENERAL REPORT

At the end of 1986, Rothamsted, like other centres comprising the United Kingdom's agricultural research effort, stands at the threshold of change. Last year's Report foreshadowed organizational changes likely to ensue from decisions of the Agricultural and Food Research Council (AFRC) to restructure its research base. Cognate activities within the broad national research programme will be linked to form eight new consolidated Institutes. These eight Institutes, constituted from about twenty existing, separate Institutes and a few Units located at Universities, will each have defined and exclusive programmes. Their Directors, together with the Secretary to the Council and his two chief executives, will provide a senior Management Board responsible for the implementation and management of Council's research policy directions.

Thus the Secretary will exercise a tighter, less extensive span of management control, and thereby ensure that the reduced resources now available for agricultural research are committed most efficiently and appropriately to developing promising areas of science. Whilst the future research will emphasize programmes concerned with efficient and socially acceptable production methods for agricultural commodities for food or animal feedstuffs, opportunities to develop the wider use of commodities as biological resources will be examined, e.g. by harnessing biotechnology to exploit established crops and plants more generally, as sources of energy, industrial organic chemicals, and pharmaceutical or other physiologically-active compounds. This broader effort will require collaboration with industry at home, with organizations in the European Community, and will develop most effectively if linked closely with the natural resources and needs of Third World countries.

It is against this background that Rothamsted becomes the largest component of a new Institute of Arable Crops Research (IACR)—a proper assignment provided higher counsels continue to appreciate that the viability of the Station (and the new Institute) requires the continuation of a wide spectrum of research linking fundamental and strategic studies to applied and practical activities. The other major component of the new IACR is Long Ashton Research Station, at present operating as another grant-aided establishment funded by AFRC and constitutionally a section of the University of Bristol. For the past two years, Rothamsted and Long Ashton have prosecuted complementary research programmes; lead status for certain research areas has been assigned to sites on the basis of local scientific expertise or geographical/regional considerations. A useful basis therefore already exists for the further integration of activities that will form a necessary part of the planning and operation of the new Institute. IACR is completed by the inclusion of Broom's Barn Experimental Station (in future to be regarded as one of the sites comprising the Institute) and the Unit of Insect Neurophysiology and Pharmacology (UINP), housed within the Department of Zoology of the University of Cambridge. Broom's Barn conducts multidisciplinary research seeking to improve the sugar beet crop, and its work is financed entirely by the Sugar Beet Research and Education Committee (SBREC, a Statutory Body administering 'levy' funds). UINP staff are engaged in basic research on insect nervous systems and the mode of action of toxic (insecticidal) compounds; elements of the Unit's programme will be developed in concert with chemical investigations in Rothamsted's Insecticides and Fungicides Department. When the issue of privatization of The Plant Breeding Institute (Cambridge) is determined, a few posts may be transferred to IACR. The Institute will be led initially by Sir Leslie Fowden, who was appointed Director of Arable Crops Research from July 1986.

At present, only the staff at UINP are employed directly by AFRC, but staff at the other centres forming the Institute are expected to become AFRC employees during 1987; at present, personnel at Long Ashton and Rothamsted, with Broom's Barn, are employed by the University of Bristol or the Lawes Agricultural Trust, respectively, using funds from the

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grants-in-aid. The new Institute will need to acquire some form of corporate status, and it is anticipated that a new Governing Body will be created to monitor ongoing activities. The membership of this single Governing Body is likely to reflect the interests and past associations of the component sites, the need for appropriate expertise from academia and the agricultural industry, and the value of contacts with farmers, farming organizations and the community more generally. It is probable that the Institute Governing Body will be supplemented by Advisory Groups working in close association with senior managers at each main site; the Advisory Groups would identify particularly with the local scientific programmes and help generally to promote a site's work. Cross-representation between the proposed Advisory Groups and the new Governing Body would enhance mutual understanding of the responsibilities and mode of operation of each, and highlight opportunities for beneficial interactions. These Advisory Groups may evolve from the present Governing Bodies of Long Ashton and Rothamsted, the Agricultural Committee of the University of Bristol and the Lawes Agricultural Trust Committee.

The remainder of this General Introduction provides a synoptic account of the work done at Rothamsted during 1986, probably the last full year of its governance by the Lawes Agricultural Trust Committee. As another phase in the long history of the Station moves towards a conclusion, the staff take this opportunity of thanking most sincerely those distinguished individuals who over the years have given so willingly of their time to serve the interests of Rothamsted as Trustees or Committee Members of the Lawes Agricultural Trust.

Upon Sir Leslie's appointment as Director of the new Institute of Arable Crops Research the office of Director of Rothamsted formally ceased to exist. In future Rothamsted will have a Head of Station and the Trust Committee appointed T. Lewis to undertake this work in an Acting capacity.

Sir Leslie's period of 13 years as Director was marked by many scientifically important advances, including the development of a vigorous plant biochemistry programme, and major improvements to the site layout, the buildings and scientific facilities. Financial difficulties have regrettably forced retrenchment in the last few years but he has remained a stauch champion of Rothamsted enabling the Station to maintain its unique and eminent status in agricultural research.

Lawes Agricultural Trust Committee

Professor J. L. Monteith FRS resigned from membership of the Committee at 30 September 1986 upon taking up an appointment abroad. In view of impending constitutional changes affecting the role of the Committee a successor has not been nominated.

The Committee has continued to address questions of future organization and legal status, and considerable progress has been made in consultation with the Trustees, legal advisers, and AFRC.

Staff. Changes in divisional structure were proposed to AFRC in 1986 but it was agreed that final decisions must await clarification of the structure of the new Institute. In the interim A. E. Johnston was appointed Acting Head of the Soils Division and R. D. Prew assumed a coordinating role for the activities of the Physiology and Environmental Physics Department, Field Experiments Section, and the Farms. J. H. Stevenson was appointed as Acting Scientific Information Officer after 25 years' service in the Insecticides and Fungicides Department.

Staff who retired or left Rothamsted in 1986 after periods of long service included: K. Fletcher (Entomology 25), K. Smith (Engineering and Maintenance Services 31), G. T. Pearce (Farms 46), Marjorie Byers (Biochemistry 30), J. B. Free (Entomology 35), G. Brown (Soils and Plant Nutrition 39), P. H. Needham (Information and Photography 37),

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F. W. Widdowson (Soils and Plant Nutrition 40), and W. M. Corbett (27), C. A. Hodge (38), C. C. Rudeforth (30), G. M. Gosney (25) (Soil Survey and Land Resource Centre); parentheses show an individual's final department and years of service. It is a pleasure to acknowledge their contribution to the work and life of the Station. Sadly, two staff, A. R. Stone, Head of Nematology Department and Jennifer Piper, died in tragic circumstances and have been greatly missed.

The following Honours and Awards were received: L. Fowden, Honorary Member of the Phytochemical Society of Europe and Foreign Member of the Academy of Agricultural Science of the GDR, J. T. Wade, Head Caretaker—British Empire Medal in The Queen's Birthday Honours, R. T. Plumb, Head of Plant Pathology Department—RASE Research Medal 1986, T. Lewis, Acting Head of Station—D.Sc., University of Nottingham.

Buildings. The Station's attractive new Conference Hall was completed on 1 July 1986. Some problems, including the commissioning of the heating and air circulation system and the exterior landscaping and water garden, have all been resolved. The water garden, donated by the Lawes Trust, has a functional purpose in providing a source of water, if needed, for fighting any major fire on the site.

A Conference Hall has long been required and the Station now has a venue for meetings and conferences involving national and international audiences of up to 250 participants. It is already enabling Rothamsted and associated scientific organizations and societies to play a fuller part in stimulating greater scientific understanding of agricultural matters, a role in keeping with the Station's long tradition in original research and the translation of science into practice.

Because of delays in completion, no formal Opening Ceremony could be held. It is intended to arrange an evening event for Spring 1987 to mark our gratitude to those corporate and individual donors who made major financial contributions towards the cost of the building. These number over 50 and include foundations and industrial and commercial organizations in the UK, Europe, the United States, and Japan. Their names are listed at the end of this General Report, and will be commemorated by a plaque in the foyer.

In addition, the names of over one hundred staff, former staff and others from many countries associated with Rothamsted who generously contributed to the building and its furnishings and equipment are permanently commemorated in the building.

A large number and variety of smaller building and engineering projects was undertaken. The most significant was the replacement of 'Glasshouse 19' by a computer-controlled and compartmented facility for the Insecticides and Fungicides Department. Associated with this is a temperature-controlled spray room where fixed and tractor-mounted spraying equipment can be developed and tested.

Current financing. The last Report referred to reductions in research support from public funds, and to the loss of posts enforced by the need to work within a reduced cash limit budget in 1986. A further erosion of support in real terms was apparent by Summer 1986 necessitating further economies in running expenses and the loss of some forty posts by April 1987. Most of these were found by voluntary premature retirement, by writing off vacancies which had been pending firm information about the cash limit for 1987, and by deciding not to fill vacancies known to occur in future through retirement. Seven posts were identified as redundant. This was the sixth successive group of posts redundant as a result of funding reductions affecting Rothamsted and the Soil Survey. Any further cuts will necessitate the closing of whole projects. It is greatly to the credit of current staff that they remain enthusiastic and productive in these demotivating circumstances.

During the year success in attracting support from external sources including the EEC continued, in all £1·3m was attributed in this way. While partly offsetting the effects of the cuts, such short term funding cannot provide the stability required for long term work.

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Future of the Soil Survey of England and Wales. Following a ministerial decision to reduce support from MAFF by one half at April 1986, 27 posts were declared redundant. Support will be marginally further reduced in 1987–88 and in the following year and thereafter subject to further review. Negotiations were conducted for the transfer of the Survey, the majority of its remaining staff and operations to form a component part of the Cranfield Institute of Technology from an intended date in April 1987. The new title of 'Soil Survey and Land Resource Centre' has been adopted. Efforts to attract financial sponsorship from sources other than MAFF have been made with considerable success. A number of small contracts from the private sector have been obtained, and several larger ones including work related to the restoration of gas and oil pipelines, studies on nitrate pollution in soils for the agrochemical industry and water authorities, and work on landfill projects.

Opportunities for scientific interchange and publicity

At a time when science in general, and agriculture in particular, is undergoing a period of critical examination and retrenchment it is important to publicize clearly the benefits that have flowed from research and the need for the country to maintain a broad-based research input as an investment for the future. The main outlet for the Station's efforts is through the publication of its work in high quality scientific journals, but to ensure that a wider audience is reached and to emphasize the important role of Rothamsted in arable crops research, several other channels of communication have been exploited.

The 'Future with Rothamsted'. One approach was to commission an illustrated booklet of 28 pages describing current research activities and opportunities for the future. This was distributed to a varied readership including those in the agricultural and related industries, politics and government, the Universities, and international organizations concerned with research results and application.

The task of writing and design was entrusted to Colin Tudge and Colin Brewster, and the resulting publication has been widely welcomed as a clear communication of research aims and achievements. Using this material as a basis, the authors also produced a half-hour feature programme on Crop Protection at Rothamsted broadcast in the BBC's 'Science Now' series.

Rothamsted Farming Service. The first full season of the Rothamsted Farming Service (RFS), designed to foster stronger links with the farming community, was completed. The RFS, which is available on Prestel Farmlink and ICI's Agviser, makes the results of the Station's research available at the earliest opportunity to farmers and others who may be interested (*Rothamsted Report for 1985,* 14). At the beginning of 1986 the Library took over major responsibility for the management of the database on both viewdata systems. The amount of information in the database has increased considerably since the service began in December 1985. At its height in the summer there were 131 live frames of which 32 were updated weekly.

The ease with which frames can be updated makes viewdata an ideal vehicle for the dissemination of rapidly changing information such as the numbers and species of flying aphids which are monitored by the Rothamsted Insect Survey. This data in turn provides the basis for predictions on the degree of risk of barley yellow dwarf virus (BYDV) in autumn-sown cereals and of potato virus Y in home-grown seed. Similarly, continual monitoring of the pea moth, *Cydia nigricana,* enables information to be provided on the need for, and timing of sprays to control this pest. Broom's Barn Experimental Station contributes information on many aspects of the sugar beet crop including the virus yellows forecast and the spray warning scheme. Also available, but changing less frequently, is information derived from a computer model on the changing nitrogen status of five different soil types

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which can be used to determine the optimum timing and amount of fertilizer to be applied. The results of the Rothamsted Field Experiments offer information on the consequences of different agronomic practices for major and minor crops.

Talking to farmers and scientists. The Friends of Rothamsted organization, founded in 1983, is now an established feature of the Rothamsted scene. Membership continued to rise at a steady but satisfactory rate—from 250 to 290 during the year. The Friends provide an excellent forum for our scientific staff to exchange ideas with the farming community, agricultural consultants and other branches of the industry. The January meeting provided presentations followed by lively discussions on control of BYDV, straw incorporation, Broadbalk field and prospects for alternative crops. In June detailed demonstrations of four field trials studying factors affecting growth and yield of winter wheat, barley and bean crops were given.

Our scientists exhibited and described their research findings at a number of agricultural shows and other demonstrations. These included: Potato Marketing Board Open Days at Sutton Bridge, Sprays and Sprayers '86 at the National Agricultural Centre, Cereals '86 at the Royal Agricultural College, Cirencester, BASF Velcourt 'Arable Farming Under Pressure' and the Hertfordshire, Lincolnshire and Royal shows.

Other, more science-based presentations included demonstrations in the Royal Society's annual Soirées by the Biochemistry and Entomology Departments and many lectures and poster exhibits in the programmes of national scientific societies and international congresses, notably the British Crop Protection Conference in Brighton. These activities are recorded in more detail in the reports of individual departments. Rothamsted staff also played an important part in the organization of learned societies and scientific meetings.

Library activities. The Library has continued to offer a full range of services both to permanent members of the Rothamsted staff, and also, increasingly to the many workers funded by short term grants and carrying out research in a wide variety of areas. Work has continued in extending the online public access catalogue of books and it is hoped that help from the Manpower Services Commission will enable retrospective conversion of the catalogue to commence. Staff publications are now also available online.

The Rothamsted Archive which consists of a substantial body of documents, letters, photographs, laboratory notebooks and other memorabilia, has, for the first time, been catalogued with the help of a grant from the Leverhulme Trust. Access to this important body of historical material which relates to the growth and development of Rothamsted, will be possible once an index and guide to the collection is complete.

Overseas visits and visitors. Staff maintained a full and varied range of scientific contacts abroad through attendance at scientific meetings and on longer scientific exchanges or advisory visits. Over 100 staff travelled overseas and some of the longer visits took P. B. Barraclough to Purdue University, USA to study modelling of nutrient transport/uptake, H. A. McCartney to Connecticut Agricultural Experimental Station to study deposition of spores in wheat canopies, and W. Powell to East Africa to help evaluate the Desert Locust Control Organisation. Further visits to China supported by the Academic Links with China Scheme and Royal Society were made by M. G. K. Jones, T. Lewis and R. T. Plumb; D. S. Hayman went to Columbia and Brazil for lectures and discussions on mycorrhiza, J. Riley and C. J. Rawlinson visited India on behalf of the Overseas Development Administration to advise, respectively, on oilseed and grain legume crops and agroforestry, and C. Wall discussed insect pheromonal studies in Brazil.

The Station welcomed 63 visiting scientific workers from 31 countries for periods of a month or more to receive training and provide mutual stimulation in wider scientific fields. It

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is gratifying to note the frequency with which Rothamsted staff are still invited abroad to lecture or advise, and the eagerness with which foreign scientists seek opportunities to work at the Station.

Weather and crops

The year provided extremes of weather and the winter was cold and unfavourable for crop growth. Autumn-sown crops, particularly early-sown oilseed rape and cereals, went into dry seedbeds, resulting in patchy and delayed germination. November was cold with 22 ground frosts and was followed by a very wet December and January. February was the coldest since 1947 with snow cover for almost the entire period. These conditions allowed only poor growth of many autumn-sown crops and the death of most of the winter oat acreage. The late spring with a very wet April delayed sowing of spring crops. The very hot, dry June did much to help all crops catch up, although the dry surface conditions did mean that herbicides applied to the potatoes were not as effective as usual. Some cereals, particularly those in longer runs which had looked well at the end of June ripened prematurely and yielded poorly, perhaps from a combination of poor root establishment and take-all. Yields of most other crops were similar to those of 1985. Rape was harvested in good conditions in early August, and although the cereal harvest was slightly delayed it was all completed by 10 September. The exceptionally good September and October allowed the new autumn programme to be sown according to schedule and also gave excellent conditions for potato harvest.

Research highlights

At a time when the goal of maximum arable production is no longer paramount, the Station's research programme needs to strike a careful balance between solving perceived problems and looking ahead a decade or more to provide the agricultural industry with appropriate future crops and the means of growing them. The research topics chosen for comment in this General Introduction, and indeed much of the more detailed Report, reflect the Station's attempt to achieve this balanced approach. Attention is again drawn to several studies related to environmental pollution arising from agricultural practices, a concern currently near the centre of Government policy. A large, and progressively increasing, portion of the Station's work is highly relevant to solving or minimizing such problems. This type of work is complemented by a broad-ranging programme of basic studies from the molecular through the whole plant to crop level, aimed at understanding the complex processes involved in plant reproduction, growth and develoment, and how they can be manipulated to produce desirable crops. Other highlights therefore emphasize aspects of this longer-term approach, not least the important contribution made by the Station's statisticians in providing new methods of analysing the mass of data collected each year.

Soil contamination

Soil acidification. Changes in soil pH during more than 100 years under both permanent grassland and regenerating woodland have shown that soil acidifies more rapidly under woodland than under grassland. More important, however, has been the finding that the relative importance of the various acidifying inputs changes as the soils become more acid. The nitrification of ammonium ions, from the atmosphere or from fertilizers, is potentially a strong source of acidity in agricultural soils. In the absence of fertilizers, the greatest cause of soil acidification at or near neutral pH values is the dissociation of carbonic acid and the mineralization of organic matter. These results are important if one response to over-production of arable crops is to find other uses for cultivated land. Under forestry, soils may become much more acid and this could affect the acidity of leachates finding their way into

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both surface waters and deep aquifers. In the wider context of soil acidification both Woburn and Broom's Barn are now part of the UK Secondary Precipitation Composition Network which will monitor changes in acidifying inputs to the surfaces of both land and water.

Nitrate leaching. Nitrogen is lost from soil in four main ways: by leaching of nitrate, by denitrification, by volatilization of ammonium and by erosion. Fortunately the latter process does not often lead to serious losses of nitrogen in this country. The appearance of nitrates in increasing quantities in water extracted from some of the country's important aquifers is causing concern. Unfortunately nitrates are readily leached out of soil because they are very soluble in water and are not held by the soil particles. This loss occurs mainly in winter and early spring, a fact clearly demonstrated by data showing the amount of nitrate–nitrogen carried into the sea each month in the river Thames. However, relatively little of the nitrate leached in autumn comes from unused fertilizer because most crops, cereals in particular, take up as much nitrogen as they are given, certainly up to levels well above those necessary for maximum yield. Analyses of soils sampled immediately after harvest have found as little as 1% of the applied fertilizer nitrate remaining in the top 90 cm of soil. With the possible exception of heavily fertilized crops such as oilseed rape and potatoes, it would appear that most of the residual fertilizer nitrogen from spring applied dressings is in organic form in soil at harvest. These organic forms are in stubble, dead roots and their decomposition product, humus; nitrate appears in arable soils as these organic forms are mineralized. This mineralization occurs in autumn when soils are re-moistened and whilst temperatures are still high enough for microbial processes to proceed rapidly. Fertile soils can mineralize considerable quantities of organic nitrogen between harvest and late autumn—by November the heavier soils under cereals in eastern England often contain between 60 and 120 kg ha^{-1} of nitrate–nitrogen in the top 9 cm. Thus, rather than decrease the amount of fertilizer nitrogen applied to crops, a major problem seems to be to devise strategies to control either the mineralization of nitrate in the autumn or, perhaps more importantly in the short-term, ensure that soils with large amounts of nitrate in them are not left fallow during the autumn and winter period when leaching of large quantities of nitrate will almost certainly occur.

Effects of heavy metals in soils. The current guidelines for amounts of metals which may be added to soils have been based largely on the effects on soil microbial processes. In an experiment which compared sewage sludge with farmyard manure, the sludge-treated plots had more total organic matter but less microbial biomass then FYM-treated soils. This was because the sludge was heavily contaminated with various metals. Further work showed that blue-green algae grew poorly and fixed little atmospheric nitrogen on the sludged soils. Nitrogen fixation was decreased by 50% in soils containing metals at about half the extractable zinc equivalent limit and 0·8 times the total cadmium limit of 3·5 μg Cd g^{-1} soil. Pot experiments using the same soils have shown that N_2-fixation by bacteria in root nodules on clover is suppressed by the presence of the metals. When grown on sludged soil, white clover formed small ineffective nodules, the plants were nitrogen-deficient and yields much smaller. These findings have implications for the long-term fertility of soils which are now being treated with sewage sludge and highlight the need to consider not only the growth of important agricultural crops but also the growth and function of the microbial population, especially its ability to support leguminous crops which are possible alternatives to cereals in our changing agricultural systems.

Herbicide residues affecting sugar beet. Another damaging residue arising from agricultural practice appears to be that of the herbicide, chlorsulfuron, which in May and June affected patches of sugar beet at Broom's Barn after being applied to the previous winter barley crop. On this site damage was restricted to headlands but nationally some crops were severely affected. The chemical had been tested over several seasons in the UK

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by its manufacturers and was first used commercially in 1983 with little evidence of a residue problem. Much wider use in 1984 resulted in injury to sugar beet, onion and potato crops in 1986. The manufacturers have now withdrawn recommendations for its application to cereals that are to be followed by any broad-leaved crop except oilseed rape. Several companies are developing other sulfonylurea herbicides which can be expected to make a significant contribution to weed control eventually.

An explanation of why chlorsulfuron has damaged sugar beet, and a comparison of the properties that determine the mobility and persistence of these herbicides in the soil will be required to assess the chances of their damaging subsequent crops in the rotation. A computer model, developed at Rothamsted and the National Vegetable Research Station and based on current understanding of herbicide movement and degradation in the soil, failed to explain the observed performance of chlorsulfuron in 1986. Field data are needed to validate and improve the model and permit extrapolation from a few detailed experiments to predict what might happen in commercial use. The Weed Research Unit of Long Ashton Research Station based at Broom's Barn is starting field and laboratory experiments to provide the necessary data and is developing bioassay methods for residue detection.

Straw incorporation. In the Programme investigating the problems of straw incorporation (*Rothamsted Report for 1984*, 17) the major difficulty encountered this season was the presence of volunteers. On some plots where straw had been incorporated shallowly, over 30% of the ears were of volunteer wheat rather than the sown variety. The method described previously (*Rothamsted Report for 1985*, 34) for measuring the distribution of straw which has been incorporated into the soil profile by various methods of cultivation has proved very acceptable and is now being used in both ADAS and AFRC experiments on straw incorporation.

There has been concern that the incorporation of straw could cause soils to become anaerobic as the oxygen demand for the decomposition of straw could not be met by the amount of oxygen available in the soil atmosphere. Recent experiments have shown that this is not so; decomposing straw of itself is not able to use up all the oxygen and cause soils to become anaerobic unless the pore space has been drastically decreased.

Aspects of crop protection

Pathogenesis-related proteins. The pathogenesis-related (PR) proteins are well known from experimental virus hosts especially *Nicotiana tabacum* cv Xanthi-nc in which they are induced by infection with viruses, bacteria and fungi. PR proteins serologically-related to PR1a from Xanthi-nc have now been found in a wide range of hosts of agricultural importance including cereals, forage legumes, potato, tomato and sugarbeet. In addition their production is stimulated not only by virus infection, because fungal pathogens of cereals and sugarbeet have also been shown to have this effect. These results suggest that plant response to infection, as manifest by PR protein production, is a very widespread phenomenon and the conservation of these proteins during evolution in such diverse species suggests that they may have an important role in host/pathogen interactions.

Biochemical taxonomy of plant parasitic nematodes. Identification and description of economically important plant parasitic nematodes is an essential prerequisite for effective control measures. Traditional methods of identification using morphological characters are not always reliable because characters are sometimes variable and different life-cycle stages are required. Host-races and pathotypes cannot be separated using morphometric techniques.

Within the past decade biochemical methods have been used for the identification of plant parasitic nematodes. These techniques are less subjective than traditional methods

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and have the potential for separating species complexes. The main disadvantages are cost and toxicity of reagents. Research in the Nematology Department is aimed at developing and modifying biochemical methods of identification. Work so far has concentrated on using high-resolution isoelectric focusing of nematode proteins to identify species of cyst and root knot nematode and of the genus *Ditylenchus*. Cost and toxicity have been reduced by developing electrofocusing techniques with ultra-thin agarose sheets. Electrophoretic techniques have enabled the characterization of species-specific proteins which are being used for the production of highly specific and sensitive enzyme-linked immunodetection assays. Research is currently in progress to produce DNA probes specific to host-races and pathotypes. The techniques provide a viable alternative to identification using morphological characters and will lead to simple, accurate and inexpensive methods of species, pathotype and race separation.

Varroa *mite attacking honeybees.* The loss of many honeybee colonies throughout the continent of Europe has been attributed to their infestation with the parasitic mite *Varroa jacobsoni*. However its effect on colonies is still poorly understood. Previous work indicates that death of infested colonies is associated with acute paralysis virus (APV) infection. This contrasts with findings in Britain where the mite does not occur and where APV has never been associated with mortality of field bees.

The evidence from both field and laboratory studies suggests that *Varroa* mites are capable of transmitting APV from severely infected to healthy individuals, but the factors affecting the initiation of virus replication and its spread and persistence in both honeybee and mite populations are unknown. A better understanding of the dynamics of virus replication in *Varroa*-infested colonies will contribute to strategies designed to control the mite and reduce its damaging effect. Rothamsted is providing the lead in these studies for Europe.

Novel techniques for the study of aphid pesticide resistance and control. Detailed population studies of the important virus vector, *Myzus persicae,* are essential to explain how resistance develops, and to devise strategies for delaying it, but they require techniques that will monitor resistance in large numbers of individual insects. The possible contribution of novel techniques, such as immunoassay or DNA probes for the proteins or genes responsible, is consequently being examined. The suitability of the Rothamsted immunoassay for the resistance-conferring enzyme in *M. persicae* (*Rothamsted Report for 1983,* Part 1, 104) has been demonstrated during the past two seasons not only for detecting resistance but also for accurately quantifying resistance levels in as many as 3000 aphids per day.

As well as allowing study of the dynamics of resistance development in field experiments, the technique has also identified the increasing occurrence of very resistant aphids throughout the country. It is clearly important to continue monitoring the build up and the serious threat it poses to the effective control of this virus vector on field crops.

Much of the use of insecticide in the United Kingdom is aimed at preventing damage caused by *M. persicae* and other aphid species. Adverse environmental impact would be reduced by effective alternative means of control, and, of the possibilities, behaviour-controlling chemicals continue to show promise. It has now been demonstrated that the plant-derived antifeedant, (–)-polygodial, (*Rothamsted Report for 1984,* 19) can be used successfully in the field to control aphid-borne BYDV. In addition, the first identification of an aphid sex pheromone has been achieved; for the vetch aphid, *Megoura viciae,* it has been shown to comprise the two monoterpenoids nepetalactone and nepetalactol. This is an exciting chemical discovery; its potential for pest control remains to be established.

Spore dispersal in oilseed-rape. The identification last year of spores of *Pyrenopeziza brassicae,* the cause of light leaf spot on oilseed rape, high above and far down wind of a rape crop, suggested dispersal other than by rain-splash. Further work this year has revealed the

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sexual stage of the pathogen, previously not seen in the UK, on dead leaves and petioles lying on the ground under the crop. Though not visible on shrivelled dry debris, absorption of water after rainfall leads to swelling of tissue so that asci can be seen with a hand lens. Spores are released into the air, often in groups of four and usually after rain, and are airborne, not only in water droplets. These observations explain qualitatively the dispersal patterns observed in 1985, and confirm that long range dispersal of disease can occur by a mechanism other than rain splash. The presence of the sexual stage suggests much greater scope for genetic variation especially in pathogenicity and fungicide tolerance.

Crop development, physiology and genetic manipulation

Prediction of wheat development. The description of phenological development that is part of the winter wheat simulation model has been used as the basis of a prediction scheme in a project funded by MAFF. Using a database generated over a number of years in experiments at Rothamsted, Long Ashton, the Plant Breeding Institute and other sites, optimum parameter values for the model have been determined for the first time. The optimization exercise has confirmed the basic structure of the original model, and shown that the photoperiod response was underestimated whilst the temperature response was exaggerated. An improved format for vernalization requirement that can represent both winter and spring wheats straightforwardly has been incorporated, and the model has been shown to work well for a range of cultivars including autumn-sown spring wheats.

RuBP carboxylase and assimilation in field crops. Field studies on winter wheat have shown how important the maintenance of flag leaf protein content is for photosynthesis during grain filling. The rate of net photosynthesis is closely related to the amount of the CO_2 assimilating enzyme, ribulose bisphosphate carboxylase (RuBPC), over much of the leaf's life. Abundant nitrogen fertilizer increases total soluble protein and RuBPC protein per unit leaf area and maintains it over a longer period, giving greater photosynthetic capacity during grain filling. More RuBPC gives greater CO_2 assimilation when CO_2 concentration is limiting, and the extracted enzyme has higher activity per unit protein from leaves well supplied with N. However, increase in leaf photosynthesis is not proportional to the increase in protein at high N. The implication is that the higher content of protein is not used efficiently for CO_2 assimilation and that other factors control CO_2 assimilation. Agronomically, the remobilization of nitrogen from protein during grain filling requires that large amounts of protein are formed in leaves so that N may be transferred to grain to give good protein quality without greatly reducing assimilation.

Inhibitor of CO_2 assimilation present in potato leaves at night. The structure of a natural inhibitor of ribulose-1,5-bisphosphate carboxylase from potato leaves was established through collaborative research between scientists at Rothamsted, other laboratories in the United Kingdom and in the United States of America. It has been called 2-carboxy-D-arabinitol-1-phosphate though, 2-C-(phosphohydroxymethyl)-D-ribonic acid may have been more appropriate. An intriguing aspect is that synthetic 2-carboxy-D-arabinitol-1, 5-bisphosphate (CABP) has been used for many years as a tight-binding inhibitor of ribulose bisphosphate carboxylase. Natural and synthetic inhibitors are structural analogues of the transition state intermediate of the carboxylation reaction catalysed by Rubisco. Probably of considerably more significance, is the structural relationship of the natural inhibitor to hamamelose 2-C-(hydroxymethyl)-D-ribose. The natural occurrence of this sugar in plants was first reported in 1912; it is one of a relatively few naturally occurring branched chain sugars that have been found. Studies in West Germany some 15 years ago showed that hamamelose bisphosphate was made in spinach chloroplasts and was turned over rapidly in the light. A reasonable hypothesis is that hamamelose bisphosphate is a precursor or, less probably, a product in the metabolism of the natural inhibitor forming part of a regulatory

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system controlling the activity of RuBPC. Evidence for the occurrence of the new inhibitor in some 20 plant species derives from the extraction of RuBPC in an inhibited state from leaves harvested from the plants at night. In other species, including cereals, such evidence for the inhibitor is not observed. It is not clear whether such plants use a different regulating system or whether the inhibitor is destroyed during extraction.

The prospects for the development of new herbicides acting on steps in the metabolism of the inhibitor makes further studies important. Herbicides acting on particular reactions that are specific to plants must have potential advantages.

Production of somatic hybrids of potato by electrofusion. As part of the Cell Biology Programme, the use of cell biological techniques for the genetic manipulation of crop plants is being examined. For potato, the work has proceeded initially from the development of efficient procedures for regeneration of plants from isolated protoplasts, through the development of chemical and electrical fusion procedures (both analytical and bulk fusions) to the production of potentially useful hybrid plants. The fusion partners chosen were potato (48 or 24 chromosomes), and the wild species *Solanum brevidens* (which carries resistance to potato leaf roll virus, PLRV), or different dihaploid potato levels (confirmed by isozyme analysis). The use of electrofusion has been particularly effective in this work, and can give four to five times the fusion frequency obtained by chemical fusion. The hybrids will be examined for resistance to PLRV (strain B) at the Scottish Crops Research Institute (SCRI). The selected dihaploids, produced at the SCRI have also been fused at Rothamsted to resynthesize tetraploids.

Statistical research

In addition to the invaluable service provided by the Statistics Department for the wide-ranging research of the Station, the Department remains deeply involved in statistical research in its own right. This year, a major revision of the computing language, Genstat, has been completed. Genstat has been regularly updated since 1971 when the first version was developed at Rothamsted to provide more and easier access to statistical techniques, and to exploit developments in computer hardware. The latest revision (Genstat 5) includes a completely redesigned command language, high-quality computer-graphics, and much improved interactive working. The latter is essential for those statistical analyses where the scientist-statistician needs to modify his analysis depending on the inspection of data and the outcome of previous analyses. These improvements will make Genstat more accessible to people needing it only occasionally, and will provide a simpler but yet more flexible tool for the ever-growing number of people using it regularly. Genstat is used for statistical analysis throughout the AFRC, and is now leased to over 400 installations in 35 countries around the world. It operates on some 30 models of computer, including personal computers, and it is hoped that the improvements in this revision will accelerate the increase in the number of Genstat users.

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