ROTHAMSTED RESEARCH

Report for 1980 - Part 1

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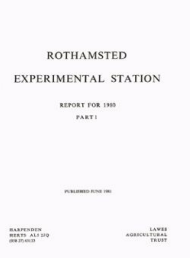

General Report

L. Fowden

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GENERAL REPORT

L. FOWDEN

Lawes Agricultural Trust. Sir Gordon Sutherland, one of our three Trustees, died in June after a short illness. Sir Gordon had served for 14 years as a member of the Trust Committee before becoming a Trustee in March 1979. He had been a good friend and respected adviser to Rothamsted during these years. The President of the Royal Society appointed Sir William Henderson, formerly Secretary of the Agricultural Research Council (ARC), as a Trustee from October. Rothamsted staff were delighted then to learn that Sir William was the recipient of the Massey Ferguson National Award for Services to United Kingdom Agriculture in November, a fitting mark of his distinction and leadership in agricultural research in Britain.

Professor Sir Kenneth Mather retired from membership of the Lawes Agricultural Trust Committee after 10 years' very valuable service. The Royal Society appointed Dr A. Spinks, formerly Research and Development Director, Imperial Chemical Industries Limited (ICI), to the Committee vacancy.

Staff. J. E. Beringer took up his appointment as Head of the Soil Microbiology Department in April, transferring from the John Innes Institute at Norwich.

Several members of staff retired after long periods of service beginning in the years indicated in parentheses: C. Bloomfield (Soils and Plant Nutrition, 1946), Margaret Holden (Biochemistry, 1944), R. H. Kenten (Plant Pathology, 1948), Barbara Mosse (Soil Microbiology, 1962), F. A. Skinner (Soil Microbiology, 1947), J. W. Stephenson (Entomology, 1950), Joan M. Thurston (Botany, 1942), N. Walker (Chemical Liaison Unit, 1950), R. A. Welch (Entomology, 1952) and A. E. Whiting (Entomology, 1961).

R. A. Dunning (Broom's Barn) gained Individual Merit Promotion to the grade of Senior Principal Scientific Officer in recognition of his contributions to sugar-beet research and production.

It is with sadness that we report the deaths of two members of the Statistics Department: Elizabeth H. Mayton and R. H. Wimble.

Honours and awards. The Station was honoured to receive its second Queen's Award for Technological Achievement. The Award marked the successful development of photostable, highly active, synthetic pyrethroid insecticides that have been exploited rapidly by the agrochemical industry under licence from the National Research Development Corporation (NRDC). Three Rothamsted compounds are now applied widely as foliar insecticides for crop protection, whilst smaller quantities are used in animal health regimes and for a variety of other purposes. In recognition of their outstanding contributions to the development of these second generation pyrethroids, M. Elliott and N. F. Janes received Inventors Awards from ARC and D. A. Pulman received an *ex gratia* payment from NRDC.

Buildings. A major refurbishing of laboratories, initially built in 1955 and forming part of the Ogg building, was completed during the year. In addition, a new single-storey building was finished to provide new laboratories for work on genetic manipulation of crop plants, and some additional space for the Headquarters group of the Soil Survey of England and Wales.

Funds for research. Last year's *Report* predicted that 1980 would be a difficult year financially. The reduced budgets for 1980/81 finally authorised by the ARC necessitated

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a stringent review of all our activities and expenditures, at a time when high inflation makes future planning difficult, particularly because inflation indices for building construction, rates and essential services and travel far exceed the percentage offset by government. It has been necessary to make savings on the salaries budget; some staff have been offered and accepted voluntary premature retirement, others have retired at ages between 60 and 63, and many vacancies have remained unfilled. The effects of these staff losses have been uneven across scientific departments, but every attempt has been made to preserve the impetus of priority programmes and important commissioned work, and to provide scientific staff with the essential major equipment and laboratory supplies vital in upholding a high level of efficiency.

Demonstrations of research

Subject days were held in mid-June and featured the topic 'Soil—basic research and its applications'. The illustrative material described research conducted principally in the Physics and Soils and Plant Nutrition Departments, and by the Soil Survey of England and Wales. The results of physical, chemical and biological investigations of soils were displayed, as well as the methods used to describe, classify and map the variability of soils mainly on the basis of the properties of profiles. Mineralogical studies providing information about the processes involved in soil formation from parent materials were explained and related to the structural behaviour of different types of soil. The dynamic behaviour of soils influences their fertility, and several relevant studies were presented: the measurement of the turnover rates of soil organic matter in relation to the microbial biomass; the determination of factors governing the release of nutrients from soil particles; and the physical description of transport processes involved in the flow of water and gases within soils and in the movement of nutrient ions towards plant roots. During 2 days, more than 450 visitors drawn from a wide cross-section of the agricultural community saw the exhibits and had the opportunity to hear short talks describing the major directions of our soils research.

Outside exhibits. The Station was involved in two demonstrations at the Royal Society's Soirées. A major exhibit devoted to the research, development and exploitation of the synthetic pyrethroids was mounted in collaboration with NRDC and the UK-based licensees, whilst a smaller demonstration describing work on aphid-trapping potato plants included a film loop showing the action and importance of foliar sticky hairs in immobilising aphids and thereby limiting the spread of aphid-borne viruses. Rothamsted contributed to ARC exhibits at 'Muck '80' (our theme being the role of earthworms in utilising farmyard manure and animal slurries) and at the Royal Show and the 'Wheat '80' event at Peterborough (where our contribution dealt with cereal aphids, their natural enemies, and the monitoring of populations and levels of acquired resistance to insecticides). Exhibits were prepared for two further events: at the spring Potato Demonstration at the National Agricultural Centre a display outlined the symptoms and the control of several important storage diseases of the potato, whilst information relating to the measurement and value of soil phosphate residues for the barley crop was included in the 'Barley Galore' event sponsored by ICI.

Visits and visitors. The Station has remained popular with visitors who have come as individuals, as small delegations or larger parties, and as participants in small meetings or workshops held on our campus. The Parliamentary Secretaries of the Ministry of Agriculture, Fisheries and Food (Mr A. W. Wiggin, MP) and of the Department of Education and Science (Mr N. Macfarlane, MP) made separate visits in the autumn to

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become familiar with aspects of our research. We were pleased also to welcome Dr D. C. Evered, recently appointed as Director of the Ciba Foundation, especially because the Foundation has decided to extend its activities to include agriculture. Individual visitors from overseas included Dr Hassan Ismail, President of the Egyptian Academy of Scientific Research and Technology, Mr S. Nishibe, Research Coordinator of the Japanese Ministry of Agriculture, Forestry and Food, Dr D. H. Saunder, Director of the Department of Research and Specialist Services of the Ministry of Agriculture of Zimbabwe, Dr L. D. Swindale, Director of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad, India, and Dr N. M. Nayar, Director of the Central Plantation Crops Research Institute in Kerala, India. Delegations of Chinese scientists with specialist interests in crop protection, insect taxonomy, insect toxicology and pedology spent one or more days at the Station, whilst a visit of a group of plant protection specialists from the USSR was sponsored by ICI and Shell. Two groups of French agricultural scientists came for small bilateral ARC–INRA discussion meetings to review collaborative work on soil–root relationships and the nitrogen requirements of cereals. The Station also hosted the 3rd European Conference on Virus Diseases of Gramineae and a Workshop involving participants from 11 countries collaborating in the EEC-funded programme on integrated and biological control of insect pests, and was the venue for meetings of the Association of Applied Biologists devoted to the topic of nematicides, and of the National Association of Seed Potato Merchants to inform members of the current position regarding the principal diseases of seed tubers. We formed longer associations with 54 visiting scientists who came from 32 countries to collaborate with departmental research teams for periods of one month or more.

Many Rothamsted staff travelled overseas to scientific conferences or for longer research visits, although only a selection of these visits is reported to indicate their varied nature. D. L. Hughes, P. R. Shewry and R. M. Wallsgrove were attached to laboratories in the USA, each to gain experience of new techniques, whilst B. J. Legg began a period of 1 year in a CSIRO laboratory in Canberra, Australia. J. A. Nelder, D. H. Rees and J. Wood made shorter visits to Australian universities and institutes. Several staff participated in specialist workshops: A. Bainbridge and J. Lacey ran aerobiology workshops in Calcutta and Mysore lasting 6 weeks; J. F. Jenkyn organised, jointly with an entomologist, workshops on the assessment of pests and diseases and the resulting crop losses as part of a consultancy to strengthen plant protection services in Thailand; and D. H. Lapwood and R. T. Plumb participated, respectively, in workshops on *Phytophthora* diseases of tropical crops (India) and barley yellow dwarf virus (Mexico). E. Lester and P. B. Tinker contributed to a symposium on root–soil relationships held in Brazil under the auspices of the Brazilian National Research Council, whilst J. B. Free, T. Lewis and R. M. Sawicki attended the 16th International Congress of Entomology in Kyoto, Japan. R. M. Sawicki also spent 3 weeks in Oman advising on the control of resistance in insects to insecticides, and M. Elliott contributed to a conference in Kenya on the use of naturally occurring plant products in pest and disease control. Mary R. Truter spent 3 weeks in March visiting and lecturing in chemical laboratories in several cities in China under the exchange agreement between the Royal Society and Chinese Academy of Sciences.

Weather and crops. The winter months were moderately cold, January being drier, and March considerably wetter than average. These conditions delayed the drilling of many experiments and the later-sown crops were affected by the subsequently long dry spell spanning much of April and May. June and July were cooler, less sunny and wetter than usual, and crops matured later than in most seasons. Harvest started in late July for winter barleys, but changeable weather in early August, with periods of violent rain,

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postponed the cutting of most cereal experiments. Harvesting was recommenced in the second half of August and proceeded uninterrupted in particularly good conditions through a dry warm September and early October, and most autumn sowings were completed in this same favourable period.

Cereals. Winter wheats and barleys were sown in good conditions in autumn 1979 and established well to survive the winter and the long dry spell in spring. Diseases and wild oats were few, and aphid populations did not reach levels requiring spraying. The cool summer gave a long period for grain filling, and generally benefited the crops, locally and nationally. Some very high yields were recorded and the national cereal grain harvest was the highest on record. The Broadbalk Classical Wheat Experiment gave the highest ever plot yield, 8·80 t ha^{-1} (a first wheat after potatoes receiving 192 kg N ha^{-1} and P, K and Mg), whilst on the best plot in Section 0 (last fallowed in 1951), the 29th consecutive wheat crop yielded 8·4 t ha^{-1}. The multifactorial wheat experiment referred to last year (*Rothamsted Report for 1979*, Part 1, 17–22) was repeated in 1980 with some modifications. Again yields were high (mean of all plots 9·6 t ha^{-1} compared with 9·7 t ha^{-1} in 1979). Fungicides again increased yields substantially (+0·8 t ha^{-1}) but, in contrast to 1979, aphicide had little effect. The greatest single-factor effect was that of sowing date; plots sown on 20 September gave a mean yield of 10·1 t ha^{-1}, those sown a month later only 9·1 t ha^{-1}. Winter-sown barleys also performed well, but crops sown rather late in spring were patchy, emergence and root-growth being retarded in the dry conditions, and showed widespread infection with barley yellow dwarf virus.

Potatoes. Experiments with potatoes are now fewer at Rothamsted. Planted in the second half of April, some crops were irrigated early in the season, but further irrigation was unnecessary in the subsequent wet summer. Aphids were few and the incidence of virus low. Harvesting was done in good conditions, and some high yields were recorded. On Broadbalk where potatoes were lifted early, several plots gave yields in excess of 50 t ha^{-1}; where the crop was not lifted until full maturity, exceptionally large yields were obtained (up to 84 t ha^{-1} at Rothamsted and up to 77 t ha^{-1} at Woburn).

Field beans. The year was reasonably favourable for both winter and spring field beans and yields of 4 t ha^{-1} were common from conventionally treated crops. The incidence of pests and diseases was greater than usual on both types. Yields of winter beans were increased from 4·0 to 4·8 t ha^{-1} by foliar sprays to control chocolate spot (*Botrytis* spp.) although control was not fully effective. A stringent regime of pest and disease control increased yields of spring beans from 3·9 to 5·6 t ha^{-1}. This increase was attributed to control of *Sitona* weevils, *Pratylenchus* nematodes, bean leaf roll virus and chocolate spot (see Multidisciplinary Activities p. 29).

Sugar beet. Little sowing occurred until late March, but progress was then rapid; 80% of the national crop had been sown by mid-April (compared with only 7% in 1979). Damage caused by mice, especially of the earliest sowings, was greater than in any year since 1974. Germination and crop establishment were also affected adversely by the unusually dry soil conditions prevailing in late April and May, although damage caused by soil-inhabiting pests was slight because they remained below the dry surface rooting layer. The crop grew slowly in the cool wet July, and at Broom's Barn full ground cover was achieved later than in most years: however, soil moisture levels were adequate to sustain good growth from August to October. The incidence of virus yellows was low, and close to that forecast on the basis of overwintering conditions for *Myzus persicae*. Mildew (*Erysiphe betae*) developed widely during August in East Anglia, but was well

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controlled by sulphur sprays; experiments indicated that where the disease occurred early, sprays applied in late July or early August gave substantial yield increases (over 25% in some cases). Nationally, the yield was slightly less than that of 1979.

The research programme: a selection of activities

Rothamsted undertakes a broad programme of basic and applied research in support of its main objective—the improvement of yield and quality of the major arable crops of the United Kingdom. The programme includes studies of the physical, chemical and biological factors that influence the formation, structure and fertility of soils and the relationship between soils and plant root systems, of the effects of environment on plant growth and the nature of the physiological and biochemical processes governing the growth, development and yield of crop plants, and of the pests and diseases of crops and the methods available for their control. Some examples of new projects or interesting developments within this programme are outlined in the following paragraphs.

Soils work

Regain of soil structure. The suitability of a soil for continuous arable agriculture depends in part on its ability to maintain good structure when cultivated. Three years ago reference was made to collaborative studies that sought to identify the main physical parameters influencing the structure and workability of soils (*Rothamsted Report for 1977*, Part 1, 14). Now, the Soils and Plant Nutrition Department and the Soil Survey have initiated a joint investigation of how quickly and well soils regain good structure after damage by traffic. In these respects, different kinds of soils behave quite differently. So far our study of structure regeneration has been confined to soil on the Rothamsted farm, which is generally known to behave well. Heavy traffic on the wet soil compressed almost all pores in the top 6 cm to less than 60 μm, and so largely eliminated the ones necessary for infiltration, drainage and root growth. However, after one season of drying and wetting under a cereal crop not subjected to further traffic or cultivation, the soil had regained enough of its original coarse porosity to allow the succeeding crop to grow well. The work so far has enabled us to test a range of techniques for measuring the rate and extent of structure regain, and the approach will now be extended to a range of other soil types of major importance in agriculture on the basis of the Soil Survey's classification, and to include soils with different reputations for structural stability.

Subsoil cultivation and fertilisation. The value of subsoil cultivation and fertilisation with phosphorus and potassium is being assessed in a new series of field experiments conducted jointly by members of the Field Experiments Section and the Botany, Physics, Plant Pathology and Soils and Plant Nutrition Departments. Early results of investigations where cultivation was by hand were very encouraging, and so the present, more ambitious programme, was started using the Wye 'double-digger' which simultaneously ploughs the topsoil and rotary cultivates the subsoil without appreciable mixing of the two layers. Experiments at Rothamsted, Woburn and Saxmundham are testing various applications of the technique (for instance, its use as a preparation of land before a period of direct drilling) and seeking an understanding of the basic mechanisms leading to increased yields. Intensive monitoring of the crop and the soil includes the measurement of nutrient uptake rates, root development, soil water use and soil structure and bulk density. ADAS has started similar experiments on a range of agricultural soils and we maintain close consultation. We are particularly conscious that it is important to establish the types of soil that will benefit most by application of this deep cultivation technique. Appropriate experimental sites must be chosen for this purpose, and informa-

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tion on the distribution of soil classes and series obtained by the Soil Survey will be invaluable. It is noteworthy that the Survey's programme of mapping necessary for the preparation of a 1:250 000 national soil map is proceeding well, if anything a little ahead of schedule.

Tillage and the physical characteristics of soil. An area of land on Little Knott field covered by a mobile rain shelter is used in alternate years to study the effects of tillage on the physical properties of the soil subjected to different water regimes. Comparisons are made between tillage (tine cultivation to a precise depth of 30 cm followed by surface cultivation and final harrowing) and no tillage treatments. Emphasis is placed on the determination of pore size distributions and the coefficients for the transport of water and heat using newly developed experimental techniques and sensors, and the data recorded should permit the separation of within- and between-treatment effects. Tentatively, we conclude that heat flow through soils of fixed water content is decreased following tillage.

Studies of plant processes. The influence of air temperature and water stress on the growth and yield of spring barley has been investigated carefully using small plots protected from rain by the mobile shelter. The data obtained has been used to adapt a model, devised in the USA for winter wheat, for Rothamsted conditions and for barley. Parameters for the Rothamsted model were estimated from 2 years' results derived after extremes of treatment made possible with the rain shelter. The model's predictive ability was assessed by comparing observed and predicted crop performance under intermediate treatments, particularly for variables such as grain dry matter and number of ears per unit ground area. Results so far show a good measure of agreement between observations and predictions and open the way to further adaptation and refinement of the original model.

Photosynthesis and photorespiration. During the year new staff appointments were made to boost our research effort on carbon metabolism during photosynthesis and photorespiration as part of an ARC-coordinated priority programme. A major part of the Rothamsted programme centres upon the purification of RuBP carboxylase/oxygenase, an enzyme whose properties are crucial in governing the relative activities of photosynthetic CO_2 fixation and photorespiratory CO_2 evolution. Availability of the purified protein from important crop species should facilitate a precise description of the relationship between the molecular structure and catalytic activity of the enzyme, and thereby indicate ways in which photorespiration might be regulated in future. In addition, mutants of barley have been screened to detect irregularities in their photosynthetic metabolism. With certain non-agricultural species, this has proved to be a particularly effective technique enabling the role of specific enzymes in the photorespiratory cycle to be identified.

Genetic manipulation of crop species. New impetus for this priority programme was provided late in the year by the completion of a dedicated laboratory building. Meanwhile, our scientists have regenerated, for the first time in Britain, potato plants from isolated protoplasts using the commercial tetraploid cultivar, Maris Bard. The procedures developed were novel for tetraploid cultivars and make use of fully defined media, a prerequisite for planned future work on the selection of biochemical mutants and in transformation studies. The agronomic characteristics of the regenerated plants will be tested in conjunction with plant breeders to ascertain whether they show the range of variation reported by workers in other countries.

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The first mutant lines of barley selected under the programme have been characterised biochemically. Seedling plants developed from embryos selected for their ability to grow on lysine plus threonine possess enzymes with altered regulatory properties and produce increased amounts of threonine both in the vegetative tissues and in seed obtained from mature plants. This threonine is accumulated in the soluble nitrogen fraction (i.e. non-protein component) of the grain in amounts sufficient to increase the total threonine content of the seed. Threonine is the second most nutritionally limiting amino acid (after lysine) for non-ruminants fed only barley and so this or similar mutations ultimately may find a commercial application: meanwhile, such mutant selections are important in furthering our understanding of the basic biochemistry of amino acid synthesis in plants and as markers in transformation experiments.

Pesticide chemicals, farm wastes and the environment. Last year (*Rothamsted Report for 1979*, Part 1, 15) I commented on the *Report of the Royal Commission on Environmental Pollution: Agriculture and Pollution* (Command 7644, September 1979) in the light of on-going research at Rothamsted. Several interesting developments occurring during 1980 bear on two topics, pesticide usage and farm wastes, featured in the *Report*.

Resistance of insects to insecticides. Excessive use of insecticides applies unnecessary selection pressures to insects and may lead to loss of control through resistance. Probably the most important mechanism of resistance to pyrethroids, and some other insecticides, is known as *kdr* (knock-down resistance); the nervous systems of insects with this type of resistance are less sensitive to the effects of insecticides. Recent research with houseflies has shown that this changed response is associated with an alteration in the properties of membrane lipids. This finding may help to elucidate the nature of the *kdr* resistance mechanism and the fundamental mode of action of pyrethroids and to facilitate the unequivocal identification of the mechanism if present in the same form in other arthropod pests.

Pyrethroids as control agents in virus transmission. Collaborative work between members of the Insecticides and Fungicides and the Plant Pathology Departments has established that the potent pyrethroid deltamethrin (earlier called decamethrin, 'NRDC 161') prevents or greatly diminishes transmission of plant viruses by the peach potato aphid (*Myzus persicae*) even at sublethal doses. Deltamethrin, and other pyrethroid insecticides, unlike insecticides of other chemical groups, apparently act sufficiently rapidly on aphids alighting on sprayed foliage to suppress probing and thereby to restrict transmission even of the non-persistent potato virus Y. This finding suggests that it may be feasible to lessen virus transmission by the appropriate use of pyrethroid insecticides.

Chemical spray application systems. Acceptable levels of weed, disease and pest control could be achieved with reduced quantities of pesticides if these could be directed towards their target organisms more efficiently, as in the electrostatically charged spraying systems we are developing (*Rothamsted Report for 1979*, Part 1, 16). In the past year, we have designed and developed a new charged rotary atomiser to operate with oil- or water-based formulations. Field trials using both hand-held and tractor-mounted equipment confirmed earlier findings, establishing that charged sprays provide better droplet distribution, less drift, increased deposition of the sprayed compound, and improved under-leaf coverage than uncharged rotary or hydraulic sprayers.

Earthworms and farm waste disposal. Work done over many years in the Entomology Department has provided basic information on the taxonomy, biology and ecology of

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earthworms, and we are now able to apply this knowledge to the prospect of using earthworms to convert farm manure and other wastes into friable and odourless composts rich in available nutrients and, at the same time, provide large amounts of high quality protein for pig, poultry and fish food. This possible exploitation of organic wastes as an immense reserve of food for stock production presents an exciting challenge.

Earthworms contain 60–70% protein on a dry matter basis. Several species, especially *Eisenia foetida*, breed rapidly in organic waste reaching maturity after 7–8 weeks, thereafter producing two to three cocoons weekly, each containing two or more eggs. We have begun investigations seeking information about optimal culturing media, temperature, pH, and degree of aeration necessary to produce maximum conversion of farm animal waste to biomass.

Mechanical methods for separating the worms from pig and other waste are already available through developments elsewhere but their improvement and adaptation to UK requirements are planned in collaboration with the National Institute of Agricultural Engineering. One aim is to provide farm scale methods of breeding worms from pig manure so that all the supplementary protein needed for a herd of pigs could be generated from their own waste. It may be possible also to lessen odour from piggeries by passing vent gases through earthworm casts which are an effective deodorant. Generally, there seems no reason why the production of earthworm protein from a wide range of organic wastes should not be commercially attractive on a farm or industrial scale.

Computer-based data- and word-processing facilities

Progressively, with time, the data-processing equipment used by the Statistics Department had become outdated and unreliable, and replacement by a modern system had become imperative if an efficient statistical analysis service was to be maintained for our scientists and those in other organisations such as ADAS. In choosing new equipment, we sought a system that would meet fully the needs of statisticians and also provide a word-processing facility for administrative and clerical purposes. The AM Jacquard J100 system was selected and, after developing a program suitable for our specialised data entry purposes, the equipment now services these dual requirements of the Station satisfactorily.

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