ROTHAMSTED RESEARCH

Report for 1974 - Part 1

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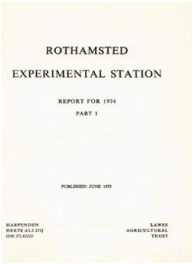

General Report

L. Fowden

L. Fowden (1975) *General Report ;* Report For 1974 - Part 1, pp 9 - 16 **- DOI: https://doi.org/10.23637/ERADOC-1-131**

GENERAL REPORT

L. FOWDEN

People receiving last year's Annual Report were asked to complete a questionnaire about their attitude to its length, style and scientific content. We thank those many readers who took the trouble to return the questionnaire. This year's Report shows some changes in arrangement of material which we believe to be desirable; in part they reflect comments expressed by readers. For the first time Departmental Reports are arranged alphabetically. Generally they are a little shorter than in immediately past years and are introduced by a staff list and end with a list of publications. Abstracts have been omitted. In future, Part 2 of the Report will not contain general reviews but will be reserved for the publication of results of long-term experiments performed at the Station.

Lawes Trust Committee. Members of the Committee and Staff of the Station were delighted that Lord De Ramsey, Treasurer, was honoured by being created a Knight of the British Empire in the Queen's Birthday Honours 1974. His knighthood was conferred in recognition of his outstanding services to agriculture. All associated with the Station were distressed to learn of the accident sustained by the Trust's Chairman, Sir Richard Verdin. We hope he will make a full recovery for his wise counsel has been missed at meetings this year. Dr. J. Ramsbottom OBE died on 14 December, aged 89. He had served as the Linnean Society's representative on the Trust Committee from 1938 to 1972.

Staff. H. L. Penman retired at the end of March. He had spent almost the whole of his scientific career at Rothamsted, joining the staff in 1937 and becoming Head of the Physics Department in 1954. His outstanding contributions to agricultural physics, especially meteorology and hydrology, brought recognition of many types. He served as President of the Royal Meteorological Society (1961–63) and was awarded the OBE and elected to Fellowship of the Royal Society in 1962. His advice concerning the effects of climatic factors on crop growth was sought by many countries and organisations. But to most people he will be remembered best by the 'Penman formula' predicting water loss by natural evaporation from soil, water or crop surfaces.

J. R. Moffatt also retired this year (December) after an even longer period of service. After graduating from Wye College in 1931, Moffatt joined the farm staff as a recorder. His energy and skills were quickly recognised and he was appointed to manage the farms in 1934. During his 40 years as Head of Farms the acreage under cultivation has doubled and the number of experimental plots increased from about 1000 to 10 000 annually. Moffatt's strong management always ensured the satisfactory completion of the programme of field experiments, and the Station's scientific staff record their gratitude to him. R. Moffitt, who served as Moffatt's deputy since joining the farm in 1961, has been appointed Head of Farms from 1 January 1975.

A. S. Primett and C. R. L. Scowen retired after periods of more than 20 years valuable service. W. D. Brind, Director of the Commonwealth Bureau of Soils which is located at Rothamsted, also retired during the year. C. A. Oggelsby, a member of the Engineering and Maintenance Department, died suddenly in October.

The Station's services were strengthened by the appointment in September of P. J. Thornton to the new post of Station Engineer and Head of the renamed Engineering and Maintenance Department. We also welcomed W. Mather as a new Assistant Secretary in Central Administration.

https://doi.org/10.23637/ERADOC-1-131

Honours and awards. M. J. Allen was honoured by being made a Member of the Order of the British Empire in the New Year's Honours 1975. V. C. Woolnough, foreman at Saxmundham, was awarded a British Empire Medal in the Queen's Birthday Honours 1974.

Buildings. The outline of our long-term development plan for the campus became clear early in the year and detailed planning of the first buildings in the programme went ahead against a steadily worsening financial climate. Work was begun on a new entrance road prior to beginning an extension to the Daniel Hall Building providing additional offices for the Statistics Department. Planning permission was obtained for a new laboratory block to house the departments of Entomology and Molecular Structures, and for a spur to the Ogg Building to provide more adequate laboratories for some members of the Insecticides and Fungicides Department and the Chemical Liaison Unit. The Staff Union, helped by grants from the Lawes Agricultural Trust and the ARC, completed an extension to the Sports Pavilion that will permit the more satisfactory separation of general social activities from changing facilities.

The organisation and funding of research. Last year I gave a brief account of a new system based on the Joint Consultative Organisation (JCO) for ensuring that national priorities were reflected in the programmes of the Agricultural Research Council (ARC)-sponsored research institutes. Staff from Rothamsted have joined two new JCO Committees, G. W. Cooke and K. E. Clare as members of the Soil Science Committee, and I. J. Graham-Bryce, F. G. W. Jones and L. Fowden of the Plant Science Committee. However, the mechanism for determining priorities is still in an embryonic stage and as an interim arrangement selected projects chosen from on-going work at each institute have been grouped to form 18 large commissions financed by money transferred to the Ministry of Agriculture, Fisheries and Food (MAFF). In 1975 slightly more than half the research conducted in institutes will be financed in this way and, by a nice coincidence, the proportion of Rothamsted's programme commissioned will equal the national figure, although the percentages of work included from our different scientific departments varies widely. This is partly a reflection of MAFF's preference to commission the more applied aspects of our research programme.

A co-ordinated programme of research and development in agriculture can be planned and executed only by effective collaboration between different sectors, and it is then satisfying to record that ADAS responded wholeheartedly to our suggestion that together we should examine how our mutual interests in the areas of soil science and crop protection might be developed. Agreement was reached that closer association in practical work would benefit problems concerned with the measurement of maximum yields on different kinds of soil, heavy metals in sewage sludges and soils, nitrate in surface and drainage waters, physical properties of soils in relation to cultivation, and the value of phosphorus and potassium reserves in soil in terms of more rational fertiliser use. Biological research identified as appropriate for close collaboration included work on nematode pests of beans, the development of resistance to insecticides by insects, pest incidence and monitoring, and the control of soil pests.

Assured research funding is essential for the effective development of such collaborative programmes and of work to meet the requirements of commissions, yet in November the Secretary of the ARC had to tell listeners at a conference held at the Farmers' Club that the 'agricultural research service is now a shrinking service'. As part of a programme of reduced government expenditure, the grant received by ARC in the present financial year was cut by about 6%. With inflation also pushing up costs at an alarming rate, not least those of rates and essential services, other forms of expenditure have had to be

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drastically curtailed. Purchases of major items of capital equipment suffered most severely. Clearly any continuation into future years of this alarming equipment run-down would rapidly lead to a loss in efficiency and a decline in standards of research. An embargo on the filling of vacant posts within the agricultural research service was announced in October as a crude but speedy way of releasing additional funds for equipment and other essential services. At a time when all economic and political considerations indicate that Britain should become more self-sufficient in food production, the wisdom of extending the cuts in government expenditure to agricultural research is surely questionable.

Demonstrations of research

Rothamsted. Open days for visitors, especially local residents, were arranged on a July weekend. A very wet Saturday restricted visiting to the laboratories and the Manor House, but over 1000 people including Mr. Victor Goodhew (Member of Parliament for the St. Albans constituency) and his wife showed great interest in the many exhibits. The sun came out on the Sunday, and so did the crowds. The Mayor and Mayoress of St. Albans were among some 4000 guests who enjoyed the field experiments, farm tours and meteorological station as well as the indoor demonstrations. We received many appreciative comments from visitors who had gained a better understanding of the methods and objectives of agricultural crop research.

Another major event was a scientific and technical Subject Day devoted to field beans. On this occasion, an invited group of 150 people were able to see and discuss the Station's interdisciplinary work on this important legume crop. Our visitors included Dr. W. G. Henderson, Secretary, and his senior administrators from ARC headquarters, Dr. H. G. Pereira, Chief Scientist, and members of his group at MAFF, Mr. J. C. Martin, Chairman of the Arable Crops and Forage Board of the JCO, senior headquarters staff and advisers from the Agricultural Development and Advisory Service (ADAS), research scientists from the government, university and commercial sectors, farmers and representatives of the agricultural press. If beans are to become a more important crop in Britain, good and reliable yields are needed. Our work has shown that viruses and stem eelworm can cause dramatic losses and the Subject Day stressed the importance of planting healthy seed, since poor stock can carry both viruses and eelworms. The public discussion of these problems both during and after the Subject Day stimulated a re-examination of the field bean certification scheme which at present does not embody statutory checks for eelworm and viruses. Next season ADAS, in association with the National Institute of Agricultural Botany, aim to examine on an advisory basis soil and seed samples for stem eelworm, and to help examine pre-basic and basic breeders' stocks for virus.

Saxmundham. The year marked the 75th anniversary of the Saxmundham experiments, and the 10th anniversary of Rothamsted's acceptance of responsibility for this Experimental Station in Suffolk. The occasion was marked by an Open Day which aroused considerable interest among farmers and helped to establish closer links with local officers of ADAS who wish to make more use of our results in their advisory work. The soil at Saxmundham (Calcareous Boulder Clay of the Beccles series) is typical of the sandy clays occurring in Eastern England and provides an opportunity for investigating the effects of poor soil structure on crop yields. The liability of the structure to deteriorate seems to be an inherent feature determined by the soil's mechanical composition. Some of the Saxmundham experiments compare the value of phosphate residues accumulated during long periods of known manuring and the capacity of the soil to release potassium with similar parameters determined for Rothamsted and Woburn soils. Others are

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designed to extend our knowledge of cereal diseases, crop rotations and herbage production to this more difficult farming situation. A fuller account of the work at Saxmundham appears in Part 2 (pp. 187–194) of this report.

Visits and Visitors. Many agricultural scientists and administrators visited the Station during the year. We were especially pleased to welcome the members of the JCO Arable Crops and Forage Board in October, and to discuss those aspects of our research which particularly interested them. Among individual visitors we welcomed Mr. J. D. Hutchison (RHM Centre), a new Council member of ARC, who acquainted himself with some of the Station's major research programmes. Senior Australian scientists included Sir Rutherford Robertson (Canberra), immediate Past-President of the Australian Academy of Sciences, Dr. F. G. Lennox, Chief Scientific Liaison Officer attached to the Australian High Commission in London, and Dr. E. M. Hutton, Chief of the CSIRO Division of Tropical Agronomy (Brisbane). Two members of the New Zealand High Commissioner's staff, Mr. M. D. Gould and Mr. C. M. Palmer, respectively Agricultural Attache and Scientific Liaison Officer visited us in June. We had a brief but scintillating visit from Col. Bernasko, Ghana Commissioner for Agriculture, and Professor V. A. Kovda, President of SCOPE (Scientific Committee on Problems of the Environment) and Director of the Institute of Agrochemistry and Soil Science of the Academy of Sciences of the USSR, nicely combined discussions on soil science with partial participation in the events of Subject Day. Our biochemists had a visit from Professor P. Olesen-Larsen, Chairman of the Danish Science Research Council. In addition, the Station offered its traditional hospitality to parties of school children, students from universities and polytechnics, members of farming and allied organisations, and general groups interested to learn more of our activities. Every continent and sub-continent was represented among longer-term visiting workers attached to our scientific departments during the year.

Requests for secondment of Rothamsted staff to overseas assignments appeared more numerous than ever before, and many of our scientists spent periods abroad, especially in developing countries, contributing experimentally to the solution of local problems or acting as advisers, teachers or consultants for agricultural programmes. Often these visits were made at the request of the Food and Agricultural Organisation (FAO) of the United Nations or our government's Ministry of Overseas Development (ODM). Interesting examples included visits by J. A. Nelder (Caribbean) and P. Walker (Philippines) to advise on biometric projects, F. G. W. Jones (Peru) and A. R. Stone (Venezuela) as advisers and collectors of nematodes attacking potatoes, P. Etheridge, F. T. Phillips and G. C. Scott (Brazil) to conduct field trials of new toxic baits for leaf-cutting ants, T. Lewis (Seychelles) to assist in the crazy ant project, C. A. Edwards (Bangalore) as consultant and lecturer in plant protection programmes, especially in relation to soil pests, and L. Fowden (Trinidad and Jamaica) to review agricultural projects supported by ODM.

Many other staff travelled overseas to attend international congresses; in particular the Station was represented strongly at the third International Congress of Pesticide Chemistry held in Helsinki. L. Fowden participated in the Deutsche Akademie der Naturforscher Leopoldina symposium on 'Evolution of Secondary Metabolism' held in the Wartburg Castle near Eisenach, East Germany.

Weather and Crops. Farm work was made difficult by abnormal weather which influenced crop yields in highly selective ways. The mid-winter and late-autumn months were very mild but all months in the period May–October were cool. The year's rainfall was above average. Rain at the beginning of the year was heavier than normal, but very little fell in March, April and early May. The months of September, October and November

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were unusually wet and precipitation was almost double the mean for the period. These vagaries of weather resulted in poor yields of sugar beet; virus spread was favoured (see below), whilst harvesting from extremely wet land was delayed and tiresome. In contrast, some high yields of potatoes were recorded, although lifting was again delayed.

National wheat yields averaged about 0·5 t ha^{-1} more than in 1973, a result partly due to the increased proportion of the crop represented by Maris Huntsman and other 'high yielders'. However, yields on Broadbalk field, where Cappelle was retained as our standard variety, were at least as good as 1973, suggesting the year was generally good for wheat provided harvesting was completed before the heavy rain of September. A plot yield for wheat (Maris Huntsman) in excess of 60 cwt $acre^{-1}$ (7·5 t ha^{-1}) was recorded for the first time on the difficult Saxmundham land. By contrast, the mean yield in the wheat variety trial performed on a 'healthy' site (free from soil-borne cereal diseases) at Rothamsted was slightly lower than in 1973. The new semi-dwarf variety Maris Fundin gave a high yield (7·3 t ha^{-1}) on this site but severe infection by eyespot on a 'diseased' site (following barley) markedly reduced yield (5·4 t ha^{-1}).

Beans grew slowly at first in dry ground, but after June rain the crop grew rapidly and remained green into September. Ripening then occurred quickly and some good yields were taken. At Rothamsted, virus-free seed of the variety Minden planted in nematode-free soil gave 5·7 t ha^{-1}—over twice the average yield of the last few seasons. Minden also gave a good yield (5·0 t ha^{-1}) on one field at Woburn.

The high autumn rainfall delayed potato harvesting and resulted in quite large tubers, generally of good shape and with little disease, except in areas of waterlogging where tuber rots developed. Yields of established varieties at Rothamsted were 6–8 t ha^{-1} higher than in 1973; the newer varieties, Stormont Enterprise (58 t ha^{-1}) and Maris Piper (58 t ha^{-1}) performed well. At Woburn, Stormont Enterprise yielded 63 t ha^{-1} in one experiment.

Some work on soils. Since 1957 the Soil Survey of England and Wales has recorded the types of soil at all sites of fertiliser experiments with sugar beet carried out by Broom's Barn Experimental Station. The information is now being analysed to discover which soil factors affect yield and response to fertiliser, and the extent to which classification of the soil helps to predict either yield or response. Preliminary results show that there are appreciable differences between the main types of soil, and that silt soils and soils of moderate drainage yield most. The work promises to be of value if agricultural policy requires a larger acreage of sugar beet to be planted.

The movement of nutrients in soil depends largely on hydrodynamic dispersion, a process involving simultaneous movement of water and dissolved salts. Important examples of the process include the leaching of salts from soils, the movement of nutrients towards plant root systems, and evaporation from saline soils. A mathematical approach to hydrodynamic dispersion has been developed in the Physics Department and applied to some laboratory and field problems of solute movement. Work in the Pedology Department draws attention to the persistence of extractable toxic metals in soils many years after treatment with sewage sludge, and shows how liming mixtures of sludge and soil can cause unpredictable changes in their extractabilities.

Energy and nitrogen utilisation. Roughly 2 kg of crude oil are needed in the manufacture and distribution of the nitrogen fertiliser providing each kg N for crops. Other calculations suggest that as much as a third of the energy input (excluding solar radiation) needed to maintain intensive agricultural systems is used to produce nitrogen fertilisers. These high energy costs, painfully translated into farmers' expenditure in 1974, re-emphasise the need to continue our research aimed at reducing losses of fertiliser nitrogen

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by leaching and denitrification and at the maximum use of nitrogen reserves in soil and biologically-fixed nitrogen. The energy needed for biological nitrogen fixation is derived ultimately from photosynthesis. Although we lack good estimates of the quantity of photosynthate necessary to elaborate the nitrogen-fixation infrastructure and to drive the reductive reaction, the high yields attainable by legumes without nitrogen fertiliser suggest that the energy requirements can be met readily. They may be of the same magnitude as that needed for the uptake, translocation and reduction of nitrate by plants.

Staff in the Soil Microbiology Department are attempting to unravel the complex biological processes involved in nitrogen fixation in legume nodules and aim to produce symbiotic associations better adapted for increased productivity. Under good conditions a forage legume can fix annually more than 300 kg N ha^{-1} and a grain legume about half this amount. Using red clover as a model system, selection by breeding of the components for enhanced nitrogen fixation is demonstrating the potential for appreciable yield increases. High productivity in legumes depends upon the development of adequate numbers of root nodules with high nitrogen-fixing potential, which in turn requires that agricultural soils contain compatible, fully effective strains of bacteria. The problems surrounding the artificial introduction into soils of better strains of *Rhizobium* are receiving increased attention.

The immediate end product of nitrogen fixation or nitrate reduction is ammonia. The metabolic processes used by plants to assimilate this ammonia into organic nitrogen compounds attract the interest of our biochemists. Glutamate produced by the enzyme glutamate dehydrogenase generally has been regarded as the primary product of ammonia assimilation, but new experiments indicate that this pathway is less important in some leaves and roots than an alternative route involving the initial incorporation of the ammonia-N into glutamine and its subsequent transfer to α-oxoglutarate to form glutamate. The two enzymes required in this alternative mechanism are present in plant tissues in amounts commensurate with a primary role in ammonia assimilation, whereas the levels of glutamate dehydrogenase and its affinity for ammonia both appear too low for efficiency in this role.

Pest forecasting and control. Much of the work of the Entomology Department is concerned with methods for monitoring pests with the aim of giving early warning of their presence in particular areas and of forecasting the likely populations of particular species, so that effective control measures can be applied. The confidence of agricultural advisers and farmers in the ability of the Rothamsted Insect Survey to anticipate pest infestations has been strengthened by recent results with potato aphids, the vectors of viruses, especially leaf-roll, in Scottish seed-growing areas, and with *Rhopalosiphum insertum*, an aphid damaging apples and requiring systemic insecticidal sprays in southern England. The population forecast for bean aphids organised in association with Professor M. J. Way (Imperial College London) also correctly predicted the heavy infestation of spring beans observed in 1974, and has indicated that much smaller populations are likely in southern England in 1975.

An experimental method for monitoring pea moths in crops has shown considerable promise. Sticky or water traps, containing either live virgin females or an extract containing natural pheromone, were used as lures for males. Catches were much larger than in suction traps and the presence of moths could be detected at much lower population densities. The pheromone-type traps should indicate the arrival of immigrants into pea crops sooner than suction traps or the present monitoring system based on searches for eggs, and so provide more accurate local assessments of the need to spray. We hope to organise a large-scale field trial of the new system in association with ADAS entomologists during 1975. Meanwhile, work on the isolation, characterisation and synthesis of

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the pea moth's natural pheromone is proceeding in co-operation with members of the Insecticides and Fungicides Department.

In recent years our pathologists have devoted considerable attention to the two weevil-transmitted viruses, broad bean strain (BBSV) and Echtes Ackerbohnenmosaik-Virus (syn. broad bean true mosaic, BBTMV). *Apion vorax* has been identified as the main vector, and a better understanding of its biology should aid virus control. The weevil's normal winter habitat appears to be woodlands and hedgerows and virus may spread more rapidly in bean crops growing close to patches of trees or shrubs. Both viruses persist in the seed, and *A. vorax* transmits virus within a crop having some plants infected from the seedling stage rather than by bringing virus into a clean crop. Clean seed perhaps may be produced more easily in areas of Britain where the vector is unknown or rarely encountered. Peas are susceptible to infection by BBSV and BBTMV, but field crops may be protected from the viruses because the plants are apparently distasteful to *A. vorax*.

Work on the chemical control of nematodes has developed well. Oximecarbamates, especially aldicarb and oxamyl, if well worked into the top soil prevent serious damage of crops by cyst-nematodes and either prevent or markedly restrict increase in nematode populations. Good protection was achieved in a wide variety of sand, peat, silt and clay soils.

Virus yellows of sugar beet. Last year's Report predicted that another mild winter could lead to severe infection of the 1974 crop by virus yellows. Both occurred, beet areas in England experiencing the worst epidemic of yellows since records started over 30 years ago. The severest outbreaks occurred in southern East Anglia, but by the end of the season crops in most parts of England were predominantly yellow. Sugar beet crops in Belgium, north-east France, southern Netherlands and parts of Germany suffered equally severe infections.

Winged *Myzus persicae* first infested crops in May, and they were far more numerous during May and June than in any previous year since 1961. The aphids, apparently carrying yellowing viruses, entered backward, patchy crops caused by slow and irregular seed germination in dry soil, and every plant had many chances to become infected. Disease was spread uniformly throughout the crop, there being little evidence of patchy infection developing from foci as in past years. Well-timed sprays delayed infection, but failed to give adequate control. Better results were obtained with granular pesticides incorporated in the soil. The poor control given by insecticidal sprays can be attributed in part to a combination of unfavourable conditions (small plants often suffering water stress, desiccating atmosphere, and particularly heavy and sustained aphid invasion), but records show instances where well-applied and repeated applications failed to kill green aphids present on plants. Tests have established beyond doubt that aphids resistant to organophosphorus insecticides were present in some field crops, although there is no evidence that such resistance was a significant factor in the yellows epidemic. However, concern must exist when about one-third of aphid samples taken from beet crops tolerated in systemic tests ten or more times as much dimethoate or demeton-S-methyl as the most susceptible aphids and research to find alternative insecticides for controlling resistant *Myzus persicae* is continuing with all possible speed.

The development of new pyrethroid insecticides. Two pyrethroids, resmethrin and bioresmethrin ('NRDC 104' and '107', respectively), synthesised earlier in our Insecticides and Fungicides Department now have an established place in commercial formulations where safe, powerful and non-persistent insecticides are required, especially for the control of pests indoors and in the glasshouse. Another promising pyrethroid (permethrin, 'NRDC 143') was described in last year's Report; although chemically related to those

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developed earlier, permethrin is more stable in air and light, under both laboratory and field conditions. Permethrin has proved very active against lepidopterous pests and in seed dressings to control wheat bulb fly larvae; since preliminary tests have indicated low mammalian toxicity, considerable practical use against agricultural pests can be foreseen.

A further pyrethroid (the recently synthesised 'NRDC 161') is the most potent insecticide of any class tested at Rothamsted. The compound, which contains bromine, forms good crystals and X-ray crystal structure determination by the Molecular Structures Department has conclusively established the absolute configuration of the molecule and its conformation in the solid state. This provides information important for designing other potentially active molecules.

Developments in computing and statistics. The Computer Department provides a central service for all ARC-sponsored institutes in England and Wales. The demand for computing continued to grow during 1974 and the limit of the central processor's capacity was being reached rapidly. To avert computer rationing and to ensure reliability of the service until the end of the decade, a decision was taken by ARC to install a second computer at Rothamsted, and a letter of intent has been placed for the supply of an ICL 4–72 model. It is hoped that this will become operational in April 1976. Another important development has involved the communications network linking user institutes with Rothamsted. Four remote job entry terminals have been ordered, and should be installed at some of the larger institutes before summer 1975.

The Genstat Statistical program has been further developed and converted by the Manchester Regional Computer Centre for use with the CDC 7600 computer, enabling its adoption by the University of London and CSIRO in Canberra. The first licence has been issued to a commercial firm for the IBM 360/370 version.

https://doi.org/10.23637/ERADOC-1-131