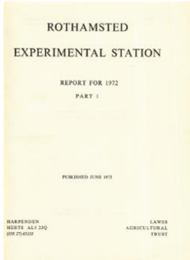
Report for 1972 - Part 1


ROTHAMSTED
EXPERIMENTAL STATION

General Report

G. W. Cooke

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GENERAL REPORT

G. W. COOKE

Sir Frederick Bawden, our Director since 1958 died suddenly on 8 February 1972. His work for Rothamsted and his scientific achievements were described in last year's Report. Professor L. Fowden, F.R.S., of University College, London, has been appointed Director and will take up his duties on 1 April 1973. After Sir Frederick's death, G. W. Cooke was appointed Acting Director and in the subsequent difficult period was helped by F. G. W. Jones (Deputy Director), E. Church (Acting Secretary) and Mildred E. Ashford (Director's Personal Assistant).

We were saddened by the death of Dr. Janina Kleczkowska on 7 June 1972, less than two years after the death of her husband. She came to Rothamsted in 1939 as a visiting worker and had been a member of the staff of the Soil Microbiology Department since 1943.

Trustee. His Grace the Duke of Northumberland, K.G., T.D., F.R.S. was appointed a Trustee of the Lawes Agricultural Trust to succeed the Most Honourable the Marquess of Salisbury, K.G., P.C., F.R.S. who died in February 1972 having been a Trustee since 1957.

Membership of Trust Committee. Dr. J. Ramsbottom, O.B.E., M.A., who had served as the representative of the Linnean Society since 1938, retired. We are grateful for his long service, for the deep interest he always took in Rothamsted's affairs and for the advice he gave us. The Linnean Society appointed Professor C. T. Ingold, C.M.G., F.L.S., of Birkbeck College to succeed him.

Staff changes. C. Potter retired on 31 March 1972 after being Head of the Insecticides and Fungicides Department for 25 years. He came to work in the Department in 1938 and succeeded F. Tattersfield in 1947. Potter was succeeded by I. J. Graham-Bryce who had previously worked in the Department from 1964–70, when he went to Jealott's Hill Research Station.

C. G. Johnson, Head of the Entomology Department, retired on 31 March 1972. He came to Rothamsted in 1946 and became Head of the Department in 1961. He was succeeded by C. G. Butler, under whom the Bee and Entomology Departments have been merged.

J. B. Bennett, Secretary of the Station since 1947, retired in September after a period of ill-health. E. Church was Acting Secretary from March until the end of the year. W. Barnes was appointed Secretary from 1 January 1973. R. K. Callow retired from the Insecticides and Fungicides Department where he had worked for the past six years. E. C. Humphries retired from the Botany Department which he had joined in 1947. Other retirements included Cita D. Cooper, N. E. Ellement, S. Foster, A. E. Pengelly and L. J. Pinney.

Under the scheme for Special Merit Promotion, C. P. Whittingham was promoted to Deputy Chief Scientific Officer.

Honours and awards. C. G. Johnson was honoured by being made an Officer of the Order of the British Empire in the Queen's Birthday Honours, 1972. G. W. Cooke was elected

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a Foreign Member of the Lenin All-Union Academy of Agricultural Sciences. C. G. Butler was re-elected President of the Royal Entomological Society of London for a second year. P. S. Nutman gave the 39th Bose Memorial Lecture in Calcutta.

Visitors. We had several thousand visitors during the year. They included a large group attending the Silver Jubilee Meeting of the British Society of Soil Science, which was based on Rothamsted; the programme of tours, visits and lectures was arranged by our staff.

Buildings and land. Throughout the year the Nematology Department continued in temporary quarters while the new building to house its members and those of the Physics, Botany and Plant Pathology Departments was being built. Construction of an additional service block was begun to provide temporary quarters for the Chemical Liaison Unit attached to the Insecticides and Fungicides Department, a workshop and implement store for the Nematology Department and storage for other Departments. Two new glasshouses were begun for the Botany Department, the Station's main car park was finished and a section of the road widened and straightened. During the year several new buildings were planned. These include a spur on the West Building to house members of the Bee Department which is now united with the Entomology Department, an office block for the Chemistry Department and extensions to the Computer and Statistics Departments. A further nine acres of light land were rented by our Woburn farm.

The future of agricultural research. During much of the year we waited for the aftermath of Lord Rothschild's Paper *The Organisation and Management of Government R. & D.* contained in the Green Paper (*A Framework for Government Research and Development*. Command 4814). The White Paper (*Framework for Government Research and Development*. Command 5046) published in July gave a plan for the future, outlining the expected 'customer-contractor' relationship and showed that by 1975–76 the Ministry of Agriculture, Fisheries and Food (MAFF) will dispense more than half of the total funds now available to the Agricultural Research Council. The White Paper did not give sufficient detail for us to discern how Rothamsted's research work will be affected by the new arrangements. By the end of 1972 it seemed that our programme will not be affected during the year beginning 1 April 1973 but that changes are likely in the following year. The requirements of MAFF as a 'customer' for research will be formulated by the Chief Scientist's Organisation prescribed by the White Paper; we welcomed the appointment of Dr. H. C. Pereira, F.R.S., as Chief Scientist. Three trends seem likely: more of our work may be planned to be of immediate benefit to agriculture and will be subject to MAFF contracts; no more *large* expansions in staff or accommodation are likely and those who receive funds for research will have to show in more detail how the money has been spent and what benefits have been obtained. We have taken part in the ARC's project identification and costing scheme for the last nine months; so far we have received no return commensurate with the large amount of extra office work involved. Rothamsted was founded to investigate problems in agriculture by scientific methods and to make practical farming more efficient. These remain our aims and we are ready to accept research projects devised for practical improvement, provided they are sound scientifically, and feasible. We have always given 'good value for money' and will continue to do so.

The following paragraphs summarise some of the work done in 1972; all the topics are concerned with practical farming problems. They, and much else besides, are reported in detail by the Departments.

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Part 1

Weather and crops. The months January to April were warmer than average, but afterwards only October and December had above-average temperatures. January to March were wetter than usual but apart from December the rest of the year was drier. The rainfall at Woburn and Saxmundham was even less than at Rothamsted. In spite of the drier and colder growing season, most crops yielded well. Cappelle-Desprez wheat grown continuously on Broadbalk yielded nearly as much as in 1971; grown after either beans or fallow it yielded ½–1 t/ha better than in 1971. In 1972 we grew 8 t/ha (64 cwt/acre) for the first time on Broadbalk; this crop was after beans and had farmyard manure (FYM). By contrast with these good yields of Cappelle the newer variety Joss Cambier suffered much more severely from yellow rust than hitherto at Rothamsted and yielded badly. At Woburn, where the summer was drier, wheat yielded less than in 1971.

Another record in our continuous experiments was with barley; Julia yielded 6·5 t/ha where a full fertiliser dressing was given on Hoosfield. In the Ley–Arable experiments barley also gave the best yield ever recorded. Barley yields were good everywhere, exceeding 1971 by 1 t/ha and 1970 by 1–2 t/ha. In some experiments yields ranged up to 8·6 t/ha (nearly 69 cwt/acre), the most we have ever harvested at Rothamsted.

Beans also yielded much better than in 1970 and 1971, and the best crops gave 3·6–4·0 t/ha, but not quite as good as those obtained a few years ago before virus diseases became a serious cause of loss of yield.

By contrast potatoes generally yielded nearly as much as in 1970 and 1971, but the record of 85 t/ha from the Woburn Ley–Arable experiment was not equalled. The national crop (6 million tons) of sugar beet delivered to the factories was barely an average yield. The cold dry summer gave small roots with less than average sugar; better weather in autumn did not make up for the bad summer.

Variability in yields. While the general trend of yields of most of our crops is still upwards, there are large seasonal variations, only some of which we can explain. The largest causes of variation recognised in recent years were from disease. Yellow rust must have limited the yields of Joss Cambier wheat in 1972, but it was not severe on Cappelle. We had little virus disease in beans and yields were better than in recent years. For the first time we used ethirimol to control mildew in all our barley experiments; probably its effectiveness is reflected in the record yields of barley. By contrast, field experiments failed to show whether drought and cool weather, or the virus yellows disease which appeared, was mainly responsible for the poor sugar-beet yields.

Crop diseases. The 1972 season had the general effect of making virus vectors late and less common than seemed likely after the mild winter. Fungus diseases of cereal leaves, particularly mildew and yellow rust, developed more quickly. The new strain of Dutch elm disease appeared on the Rothamsted estate and some infected trees were felled.

Cereals. Take-all is the most damaging soil-borne cereal disease and the only control is crop rotation. The distribution of infective fragments of plant debris in the soil is affected by ploughing, and novel methods of cultivating and sowing which move less soil may help to check the disease. Its ubiquitous nature is shown by its appearance on Barnfield where no cereals had grown for over a century; at present we take wheat and barley together in alternate years, with roots between, but it is likely take-all would be severe if we grew consecutive cereals. Further evidence has been obtained on the decline of the disease when more than three susceptible crops are grown in succession, but we have no good explanation for this phenomenon which encourages farmers to grow nearly

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continuous runs of cereals. However, farmers are warned that relying on the decline may be hazardous, especially with winter wheat; they should try to ensure that decline may be expected before risking large areas, as we have met many exceptions to the 'rule' that decline occurs after three or four crops have been grown.

Potatoes. New marketing practices may alter the effect of plant diseases. For example, King Edward potatoes, harvested immature in July and August for supermarkets are subject to rotting caused by *Pseudomonas* spp. Work we are now doing should show which stocks should quickly be sold and which may safely be stored. Rotting occurs when the tubers are washed and packed immediately after lifting; the loss is largely avoided when the crop can be dug and stored for 10 days before washing. Good potato crops depend on healthy seed. Our method of producing potato seed stocks from rooted stem cuttings is going forward for practical testing. However, better chemicals are needed to prevent pathogens (particularly those causing gangrene and soft rots) re-establishing themselves. Experiments showed that extra yields from the 'healthier' seed are not as large as had been predicted by those who complained about diseased stocks. However, the improvement is worthwhile so long as the health of seed stocks is maintained, and losses in store and at dressing and planting are decreased. The gains from using healthier stocks of King Edward as compared with commercial certified stocks amounted in 1972 to 8% extra yield, and the gain over commercial once-grown seed averaged 10%; corresponding gains with Pentland Crown were much less (4% and 1%). Healthier seed has tended to produce more and smaller tubers. This might mean less saleable yield and more of the crop left in the ground. Our experiments show that this may be overcome by planting tubers further apart in more widely spaced rows or by using extra fertiliser (the latter remedy is expensive!). During the year Dr. James Renwick, London School of Hygiene and Tropical Medicine, suggested (without proof being offered) that blighted potatoes may cause congenital malformations (*British Journal of Preventive and Social Medicine* **26**, 67). Our contribution to such problems, if real, is our long-term work to diminish the incidence of blighted tubers; most can be prevented by destroying the haulm before more than 5% of the foliage has been blighted.

Beans. The three insect-transmitted viruses were less common and damaging at Rothamsted in 1972 than in previous years. The vectors were much less numerous, probably because of the cold weather of spring and early summer. Because there was so little secondary spread the effect of roguing persisted better than in previous years. (But this was counterbalanced by less success in ridding seed of infection by heat.)

Grass occupies two-thirds of British farmland, so diseases which may limit yield are of obvious importance. Ryegrass mosaic and barley yellow dwarf virus infecting ryegrass are known; we have also recorded two new virus diseases of ryegrass using electron microscopy. Mites transmit ryegrass mosaic virus and we are studying them; the scanning electron microscope promises to quicken this work.

Pest control

Chemicals are now the accepted means of controlling pests, diseases and weeds in agricultural crops. In practice only a small fraction of the chemical is useful in killing pest, pathogen or weed; the rest is dissipated uselessly in soil or evaporates. We are therefore continually trying to make chemicals more efficient by improving formulation and application and by studying behaviour in soil. Because we wish to know much more about the distribution, movement and stability of chemicals after application we have estab-

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lished a group of chemists associated with the Insecticides and Fungicides Department. They are working with chemicals used to control nematodes and fungal diseases and with herbicides. For example much has been done on reactions of herbicides with soil; we showed this year that 2,4-D breaks down in soils previously treated with the chemical by a mechanism different from that occurring when it is applied to untreated soils. There are many common problems in work of this kind and we hope to progress better by having the chemists together.

The Insect Survey helps in planning efficient control as we need to know when pests arrive on crops. Crop sampling to find the first immigrants that warn of the possibility of subsequent damaging infestations is laborious; spraying each year as insurance is uneconomic when infestations do not develop. We have worked for four years with ADAS entomologists to show that the Rothamsted Insect Survey Traps record first arrivals of aphids on cereals better than any field sampling that is practicable. In future the Survey will be used to monitor migration and to pick out the years when migration is so late, or so small, that no spraying is needed.

Natural methods of pest control continue to be studied and the Report contains many examples of pests that are checked by disease or predators, or whose behaviour is altered by pheromones. For example, aphids are shown to be subject to fungal diseases as are wheat bulb flies; carabid beetles feed on wheat bulb fly eggs, they also climb sugar-beet plants and eat the aphids that transmit virus disease. Possibilities of sophisticated methods of control, without chemicals, will improve as we learn more about the pheromones and other substances that control behaviour of insects. Manipulating these may offer a means of control in food stores where conditions are predictable; there are also possibilities of control in the field—some substances added to soil diminish the ability of wheat bulb fly larvae to respond to exudates from wheat plants.

Nematodes. Tests of nematicides have been mostly with potatoes and sugar beet because problems with these crops are important and sites for experiments on them are readily obtained. The value of increased yield in these crops is also more likely to pay for the expense of treatment than that of less costly crops. However, the Nematology Department's work is not commodity-based. Much work on potato cyst-nematode is applicable to other cyst-nematode pests of agricultural crops, for example those that attack cereals, beet, peas and carrots. Work done on ectoparasitic nematodes of sugar beet is applicable to other crops which suffer from these nematodes. When potatoes resistant to the potato cyst-nematode and cereals resistant to the cereal cyst-nematode became available, tests with these varieties on many populations of these nematodes soon showed that not all behaved in a similar manner. Work at Rothamsted and in collaboration with ADAS, the Plant Breeding Institute, and the Welsh Plant Breeding Station, showed that both nematodes consist of a series of races or pathotypes. Whereas tests on the pathotypes of the cereal cyst-nematode have failed to show any measurable differences between them, those on the potato cyst-nematode have culminated in the separation into two species, both of which have pathotypes. A study of populations from many countries indicates that Great Britain does not have some pathotypes found on the European mainland and the second species, now called *Heterodera pallida* is more commonly found mixed with *H. rostochiensis* in some parts of Britain than elsewhere. These species and pathotypes of potato cyst-nematode may have originated in the Andes area of South America. Detailed knowledge of their distribution, inter-relationships and host ranges are vitally important to those breeding resistant varieties and to farmers who plant them.

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Soil research. While it is encouraging that applying research results on our farms continues to increase yields, we still lack explanations for much of the seasonal variability and we cannot say exactly how weather affects yields. There are large interactions between weather and disease and many of these are identified; the more complex interactions of weather with physical properties of soils, water supply to crops and nutrition remain to be unravelled. Most advances in crop production are now achieved by exploiting interactions revealed by research; our future work must attempt to identify the causes of yields being less than the maximum the weather at a site can give. Recent experiments have investigated some reasons why Broom's Barn soil gives consistently less cereal yields than Rothamsted soil. Applying nitrogen fertiliser and irrigation showed that these two treatments diminished, but did not eliminate differences between wheat and barley yields from the two soils. The remaining difference may be because Rothamsted soil is better structured.

Measurements of soil moisture in 1972 showed the value in a dry summer of water retained in the subsoil and of physical conditions that allow it to be used. At Broom's Barn barley extracted water in the soil from 100 cm deep, wheat 120 cm. Sugar beet also depended much on subsoil water in 1972; nitrate leached deep into the soil was taken up by the beet when the surface soil was too dry for the crop to use the fertiliser it contained. Experiments at Broom's Barn raise the question of whether less mobile nutrients (K, P, Mg), which do not leach into the subsoil, are inactive in dry weather. If subsoils were enriched with these nutrients would this benefit beet? In parallel work at Rothamsted new instruments were used to measure changes in nitrate concentrations down the profile of Broadbalk soil; they also showed that more nitrate is taken from the deeper layers of the soil than from topsoil.

Soil structure. There is much interest in soil problems following the publication in 1971 of the Agricultural Advisory Council's Report *Modern Farming and the Soil.* Sugar beet is sensitive to bad soil conditions and work at Broom's Barn shows that damage is often done by compacting soil when cultivating in spring; this restricts root penetration and crops take up less water and nutrients. Further damage is caused to soil when beet is harvested in wet conditions; consolidation caused in the wet harvest of 1969 was still responsible for large intractable clods ploughed up in 1972. Correcting this damage has taken three years of arable cultivation and it will doubtless have decreased the yield of intervening crops.

A lead with the difficult problem of improving structure was given by the Biochemistry Department. The liquid remaining after protein was coagulated from leaf extracts, when mixed with the badly-structured Saxmundham soil increased its pore space and made it more stable; presumably gas from fermentation of carbohydrates expanded the structure and the bacterial gums also produced stabilised it. New methods of handling clay soils to examine their structure microscopically are being developed in the Pedology Department. In past work the shrinking occurring during dehydration has altered the structure so that the results were not easily applied to field conditions. When this is avoided the results suggest that it is the very fine pores in clay soils that are altered by farming operations and that these pores determine the field behaviour of the soil.

Soil Survey. The dry weather in 1972 aided the surveyors, who worked in 28 areas and mapped 40% more land than in 1971. The inventory of our soils which is being produced is of permanent value to British farming. For example, the information collected is already indicating areas where physical properties may limit yields; the survey will become more useful as more physical and chemical properties that affect yields are measured on the soils described. Subsoil characteristics as recorded by the Survey, are

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often ignored by agronomists; their importance increases as crop yield potentials are raised. Generally our surface soils are well understood and properly handled; farmers have now the much more difficult task of understanding and managing their subsoils.

Nitrogen is the nutrient most likely to be lacking for non-leguminous crops grown in Britain and farmers spend more on N than on other nutrients. Nitrate is easily lost from soils and we continue to try to make fertilisers more efficient. Leaching losses, which can be estimated where land is underdrained and drainage outfalls are accessible, vary with winter rainfall, soil type, and cropping. We now have figures for Broom's Barn Farm where losses were 30, 61 and 7 kg N/ha (after wheat, beans and wheat respectively) in the three winters 1969–70, 1970–71 and 1971–72.

Continuing work with ammonia and its solutions in water, we have found that large dressings of ammonia nitrify more slowly than small doses. This seems an important way of simplifying nitrogen fertilisation of grass and of developing a cheap slow-acting fertiliser.

Soil microbiology. We have now established that endotrophic mycorrhiza influence the phosphorus nutrition of the host plant; this is true for different strains of the fungus, for a range of hosts, and for different soils. Plants inoculated with appropriate strains of *Endogone* grow well on soils so poor in phosphorus that uninoculated plants grow poorly or die. Ectotrophic mycorrhiza have for long been used as inocula in forests; *Endogone* fungus cannot yet be cultured but we are making some progress in growing it outside the host.

Attempts are being made to improve the performance of legumes. Results help to explain why yields of pulses are often disappointing, particularly in the tropics. Their yields may be improved by using tolerant strains of *Rhizobium*, more adaptable varieties and improved methods of growing the crops. Work on selecting and breeding for better nitrogen fixation by red clover shows that large increases in yield are possible. At present plant breeders are doing little to increase the nitrogen fixed by legumes because the field problems are so complex; integrated work involving genetics, microbiology and nutrition is needed.

Soil animals. It is often thought that the numbers of creatures living in soil are increased by organic manures and diminished by fertilisers but recent work on the soils of the Park Grass experiment did not substantiate this. Differences in numbers of animals, including earthworms, between plots treated in very different ways were less than expected. Populations were not affected by regular dressings of farmyard manure, or by large amounts of N fertilisers; soils that were slightly alkaline had more animals than acid soils. Kind of soil can have large effects on earthworm populations; they are common in Rothamsted soil but quite rare in the 'difficult' soil at Saxmundham which, being unstable when wet and easily compacted, is presumably a bad habitat.

Pollution. Work on the effect of aerial pollution on crops has started at Woburn where we suspect plants may be damaged by the emissions from brick-making factories. We are establishing equipment which will provide quantitative estimates of the yield losses occurring when the pollutants in the air are too little to cause visual symptoms.

Computing and data handling. The Orion computer closed down after eight years' service. During its time 46 791 experiments were processed and 357 353 variates analysed. Variates per experiment increased from 5·3 to 8·8 while we had the Orion. The performance of the 4–70, replacing the Orion has been much improved during the year and more users are now connected by teletype.

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As techniques of measurement become more sophisticated, much more data are generated by experiments and they may become unmanageable without powerful computer programmes to reduce and analyse them. Analysis is guided initially by an assumed model or theory, but the data themselves may cause this to be modified as the analysis proceeds. This in turn may require the data to be re-arranged and re-organised before the next step in the analysis can take place. The problems of using the computer effectively in analysing experimental data in bulk arise far more from difficulties in data-handling than from those associated with the analytical procedures. The Genstat system of programs developed by the Statistics Department provides, through its own language, a simple way of describing the structure of many kinds of experimental data and of moving them through the computing system. It also allows the user to specify compactly an important class of theoretical models to be used in the analysis. The system is designed to make the computer more readily accessible to the experimenter; at the same time the programming of general techniques of analysis helps the development of statistical theory.

Part 2

The second Part of our Report gives the results of some of our experimental work that is particularly suited to our own publication. For some of the long-term Rothamsted and Woburn experiments results and measurements are recorded in more detail than is possible in the cramped space of scientific journals; this will benefit future research. Although yields have been faithfully recorded and are easily available, details of how the experiments were managed and information about soils and crops were often sadly lacking; searching manuscripts and papers has wasted much valuable time. We hope this can be avoided in future by the full inventories of the experiments we now publish. This part of the Report also contains the review articles that we have published for many years.

This year we have a long article on the Physics Department's work on water use by farm crops. Much of it is an account of ten years of testing the neutron meter for measuring water in soil under crops. These instruments are now widely used, often uncritically: our tests, and the requirements established as essential for accuracy, are important to all who use them. The article also summarises ten years of measurements of the water used by a variety of crops.

The Reference Experiments at Rothamsted and Woburn have a never-ending use as demonstrations to visitors of the effects of fertilisers and manure; they are also essential to our scientific work. This year we show how the 15-year balance between losses of P and K in crops and gains from manuring alters soluble P and K in the soils. This information is essential for planning the manuring of a farming system; no other experiments here or elsewhere have provided such comprehensive data. Magnesium's role as a plant nutrient, and its supply from soil, is often taken for granted on heavy land. Part 2 includes an account of a 10-year experiment at Rothamsted which measured responses to Mg fertilisers. The article which describes changes in soil organic matter in our three experiments which compare ley–arable and all-arable farming systems is topical because of the continuing interest in the effect of modern farming on the soil. Other articles describe experiments on wheat grown continuously and in rotation at Saxmundham, on resistance to insecticides in houseflies and Part 2 also contains the Fourth Report of the Rothamsted Insect Survey.

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