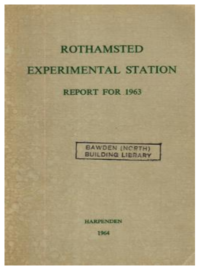
Rothamsted Report for 1963



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General Report

F. C. Bawden

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GENERAL REPORT

F. C. BAWDEN

There are some notable additions to our buildings to welcome and improved facilities for several kinds of work. The extension to the West Building, which was completed in June and occupied by the Soil Survey of England and Wales and by the departments of Biochemistry and Pedology, also provides a much-needed meeting room. Three ranges of glasshouses, an extensive "header-house", an animal house and soil store, were almost completed and will greatly facilitate work with pests and diseases. The Orion computer, with potentialities far exceeding those of our other machines, was being installed at the end of the year, when a start was also made on an irrigation system for the Rothamsted farm.

We also gratefully acknowledge two bequests by the late Dr. H. H. Mann: £1,000 for improving the amenities of Rothamsted and £100 for a permanent memorial to Dr. J. A. Voelcker. Miss Hilda Voelcker kindly presented a portrait of Dr. A. Voelcker, the father of Dr. J. A. Voelcker and the first director of Woburn.

Honours and awards. The Queen conferred honours on two members of the staff; F. Yates was appointed C.B.E. in the New Year's Honours List and R. G. Warren O.B.E. in the Birthday List. P. H. Gregory received a special promotion to the grade of Deputy Chief Scientific Officer, in recognition of the outstanding merit of his work. N. W. Pirie was elected a Fellow of the New York Academy of Sciences, and several members of the staff were among those elected by the Institute of Biology to its newly created category of Fellowship.

Visitors and visits. Swelled by over 1,200 people who came on the afternoon of Saturday, 18 May, when the Station was open to the public as part of the Harpenden programme in aid of the Freedom from Hunger Campaign, and by several conferences, we welcomed more visitors to Rothamsted than ever before. The total number is unknown, but we recorded 4,100. The many from overseas included Mr. A. Ouzegane, Minister of Agriculture and Land Reform, Algeria, Signor R. Jordan, Minister of Rural Affairs, Bolivia, Mr. L. E. Hoffmann, Assistant to Deputy Director, United States Department of Agriculture, and Dr. V. Kovda, Director of Natural Sciences, UNESCO. The several hundreds of visitors to Broom's Barn included Lord St. Oswald, Parliamentary Secretary to the Ministry of Agriculture, Fisheries and Food; an international colloquium on sugar-beet diseases was attended by 26 delegates from overseas.

Again we could not satisfy anything like all the requests we received for secondments and for staff to make advisory visits or to contribute to conferences overseas, but the departmental reports show we met several. In addition to visits recorded there, F. C. Bawden contributed to a Seminar

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on Plant Viruses and Virus Diseases at the University of Maryland in August, and in December went to Trinidad to attend a meeting of the Advisory Technical Committee for the Regional Research Centre, University of the West Indies.

The weather and crops. The bitterly cold winter, with ground under snow for more than 9 weeks and the longest spell of frost (74 consecutive nights and many days when the temperature never rose above freezing point) we have ever recorded, inevitably interfered with the programme of field experiments and affected the growth of crops. The newly designed experiment on Barnfield and some with spring-sown cereals had to be abandoned, all spring sowings and plantings were late and winter beans were severely damaged.

Autumn-sown wheat was below ground for perhaps a record period. On Broadbalk, sown late in November, there was nothing showing above ground when the snow melted in March. Although thereafter growth was rapid and yields of some plots were up to average, the attacks by wheat-bulb fly on the section after fallow proved devastating to the young seedlings; on some plots, where few wheat plants survived, the weeds took over completely and these were cut green to prevent them seeding. Yields on the section after fallow are often less than they would be but for bulb fly, but this is the first occasion when the pest has caused a complete failure. Weeds over the rest of Broadbalk, except the two half-sections sprayed with herbicides, were also more luxuriant than usual, possibly because they had so little competition from the wheat early in the year. The whole field except half of Section V will in future be sprayed with herbicides. Section Ia has been so sprayed since 1957 and was last fallowed in 1951; after twelve years of growing wheat continuously, average yields are as large as on the sections fallowed every fifth year, but there are changes on individual plots. Thus, the difference between the yield of the unmanured plot and those of generously manured plots is larger, perhaps because the leguminous weeds that used to provide some nitrogen valuable to the unmanured plot no longer do so and because on the other plots the wheat is losing less from competition with weeds. Perhaps unexpectedly, soil-borne diseases have not increased; take-all is no more prevalent on Section Ia than elsewhere on the field, and eyespot is less prevalent, a fact for which we have no adequate explanation.

After the snow melted, some of the grassland still had a white mantle, the mycelium of snow mould fungi, rarely seen here. The mycelium soon went, but the grass in some affected patches died and in others recovered only slowly.

The delayed spring was cool, dull and windy. About the only compensation for this and the cold winter was that aphid-transmitted viruses were less prevalent than in most recent years. Even at the end of September the average incidence of sugar beet yellows in root crops was only 3%, the least recorded since regular observations have been made. Green aphids did not appear on the crop until July and never became numerous, but infestations of black ones threatened to become damagingly large, and because of this many crops were sprayed. Similarly, carrot aphids were

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few and late; consequently, the crop was untroubled by motley dwarf and yielded 20 tons/acre at Woburn whether or not sprayed with insecticide. Potatoes, too, remained free from aphids during spring and early summer, but late infestations of *Aphis rhamni* were severe enough to kill the haulm prematurely.

Although yellows was unimportant, sugar beet had other troubles, and many crops grew slowly or contained patches of stunted plants. Some of these reflected soil acidity or the faulty soil structure previously found to be responsible for what has become known as "Docking disorder", but others were on neutral or alkaline soils with good structure. The beet on several such fields were infected with tomato black ring virus, which is not only transmitted by *Longidorus attenuatus* but also by the pollen and through the seed of beet. This eelworm was found on all these fields, but not on others where the stunted beet were infected with tobacco rattle virus and where the consistently occurring eelworm was *Trichodorus pachydermus*, which transmitted the virus to plants grown in pots under glass. Another soil-borne virus, pea early browning, which is transmitted by other species of *Trichodorus*, was prevalent in lucerne and peas.

Except for January, sunshine was below average for every month of the year, although there was no more rain than average. Indeed, rain was considerably less than average in May and June at Woburn, and the spring-sown cereals in fertiliser experiments suffered severely from brown foot-rot, especially those given the liberal dressings of nitrogen needed to get reasonable yields on the light land there. They promised well until mid-June, but then stopped growing, and many plants withered and died. Plots without nitrogen fertiliser yielded little, but most plants survived and matured. The withered plants were all infected with *Fusarium* sp., but what effect this had is uncertain, for so also were some plants that produced ears. Shortage of water clearly predisposes plants to the infection, but whether the fungi are active parasites or growing only as saprophytes on plants irrecoverably damaged by drought, the effect of which is probably enhanced by nitrogen fertilisers, will not be clear without further experiments.

Instead of coming in spring when the crops needed it, the rain came at harvest. Because of late sowings, cereal harvest would anyway have been late, but a wet August and early part of September meant that it could not start until mid-September, by when some barley crops were so wet and badly lain that hope of getting them in had almost been abandoned. However, a fine second half of September, and the willingness of the farm staff to work whenever conditions allowed them to, transformed the scene; yields and quality of wheat and barley were less than we would wish, but all was carried by the end of the month. Harvesting the lodged beans, which grew extremely tall and ripened very slowly, was a tedious exercise, not finished until November.

Late planting and early defoliation of potatoes by aphids meant that yields were light. Also, the proportion of saleable tubers was less than usual, for many of the Majestic were split by second growth and many of the King Edward were blighted. Although the weather favoured blight, protective sprays did not greatly prolong the life of the aphid-infested

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haulms, so had little effect on total yield of tubers, but they were nevertheless worth while because the sprayed crops had fewer blighted tubers. A dry spell in October provided excellent conditions for harvesting roots, but unfortunately ended before all the potatoes could be lifted, and some were in the ground until December. Sugar beet did better than potatoes, and although average yields were a little down, this was compensated for by an unusually large sugar content.

In general, autumn weather favoured field work, and the year ended incomparably better than it began, with winter wheat growing well and all necessary cultivations done. This means much to us with our large programme of field experiments and few farm workers; despite all possible mechanical aids, we shall remain dangerously dependent on favourable weather to complete the programme until we get more houses and can recruit more farm workers.

Fertiliser practice and experiments. The latest Survey of Fertiliser Practice shows that the amounts of fertilisers used by farmers in England and Wales increased considerably between 1957 and 1962, nitrogen by three-quarters, potash by one-third and phosphate by one-fifth. The last two increased mainly because a larger area received them, but nitrogen also increased because average dressings increased. In the whole United Kingdom the total exceeded 1,300,000 tons of plant nutrients, in the approximate ratios 49 N : 47 P_2O_5 : 42 K_2O, at a cost of over £120,000,000. The Survey tells where and for what crops these nutrients were used and provides an opportunity to see how use agrees with what would be recommended from experimental results.

Grass responds more to nitrogen than any other crop; it also uses nitrogen more efficiently than arable crops, few of which recover more than a third of what is added as fertiliser. It is gratifying, therefore, to see that the largest proportional increase in nitrogen use was on grass and in those upland areas where least was used in 1957. However, although the amount used there more than doubled by 1962, only one-quarter of the fields in permanent grass got any, compared with half in arable districts. Also, the average dressing of 19 lb/acre of the total area is pathetically little, and it is obvious that most permanent grass, which occupies some 12,000,000 acres, is producing very much less than it could. Temporary leys, especially those grown for silage, are given more fertiliser than permanent grass, but even so, only a small minority are being fully productive. Whether grass grazed by sheep or beef cattle would repay large nitrogen dressings is doubtful, but the results of experiments show that, at the current ratio of milk to fertiliser prices, well over 100 lb of N/acre could profitably be used. Few of the farmers who use nitrogen seem to do so to increase yields in mid-season and autumn, and most apply it only in spring. Nitrogen will do more than give "an early bite"; it can not only much extend the growing season at both ends but, except during drought, can also ensure continuous grazing throughout the season. So far from complicating pasture management, using nitrogen simplifies it, for not only does the extra dry matter (up to 40 lb/lb of nitrogen) mean that a given herd can be kept on a smaller area, but timing the applications to suit

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grazing needs can smooth the differences between periods of glut and scarcity that are inevitable when crops depend for their nitrogen on the contributions from clover or the soil.

The Survey shows clearly not only the neglect of pastures but also that future increases in use of nitrogen will depend mainly on more being applied to grass, for almost all arable crops are now getting fertilisers, and the total used is probably as much as is justified. Although the habit of giving only phosphate and lime in the grassland areas needs changing, it may do so only slowly, because farmers seem to be more traditional in their use of fertilisers than in other practices. It is noticeable, for instance, that although response to nitrogen would probably be greater in the predominantly grassland areas, where periods of drought are rarer, nevertheless grass in the arable areas gets much more fertiliser, presumably because the farmers there are conditioned to giving it to their arable crops. However, even in these areas, there seems to be some built-in resistance to change, and manuring becomes a matter of routine rather than anything more subtle. Over half the extra amount of nitrogen used in 1962 than in 1957 went on tillage crops. This meets requirements shown by experiments, and it would be gratifying to research workers to conclude that farmers had recognised the significance of their work, but there is little evidence that the extra was used where it was most needed, and the conclusion would be unjustified. The recognition has been by the fertiliser manufacturers rather than by the farmers, and the greater increase in nitrogen than in phosphate mainly reflects the greater proportion of nitrogen now contained in compound fertilisers. This implies that many farmers regard a given weight of fertiliser as correct for a crop and pay too little attention to its contents. As most crops previously got less nitrogen than they could profitably use, the change is welcome, but even more welcome would be an indication that fertilisers were being used more discriminately and less routinely, with the amount and kind adjusted to allow for differences in the extent of leaching during the winter and in previous cropping and manuring. Fertiliser requirement is not a fixed amount per acre for each kind of crop, but can differ greatly according to the circumstances. An inadequate dressing for one field of, say, wheat or sugar beet may be excessive for another; to give a standard dressing instead of meeting the requirement may save thinking and provide insurance against crop failure, but it means using fertilisers unwisely and inefficiently.

The ratio of fertiliser costs to prices of arable crops is smaller than ever before, and turning 1 lb of nitrogen into 10 lb of wheat shows a profit of about 400%. It can do more than this, but giving nitrogen when it produces no response is simply waste. The position is different with phosphate and potash, for when more of these is given than is needed by the crop for which they are immediately applied the excess is mostly retained in the soil and will provide food for future crops, perhaps more than 50 years later as found in some of our long-continued experiments. Nitrogen fertilisers usually leave only small residues, for most of what is not recovered by the crop to which they are applied is lost in the drainage water or to the air. Sometimes excessive use is not only wasteful but also harmful;

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with sugar beet, for example, it can depress both weight of roots and sugar percentage and increase the juice impurities. The average optimum dressing of 112 lb N/acre can be too much, especially on fields not also dressed with salt, but many farmers give more than this where it is not needed, perhaps because they are impressed by the extra vigour it often gives to the tops.

We describe many experiments testing fertiliser use, comparing different fertilisers, applied in different ways, on different soil types and to various crops. They provide too much information of practical value to summarise simply, and here no more can be said than that they will repay study and illustrate the many factors that need considering before deciding on the form and amount of nitrogen that will be most profitable.

Cereals and beans. The most striking recent change in arable farming has been the great increase in acreage of cereals, especially barley. This reflects many factors, as various as the need to make the most of expensive labour-saving machinery and the realisation that fertility can be maintained by using fertilisers. Barley has increased instead of wheat mainly because it can be grown repeatedly where wheat would succumb to soil-borne diseases, particularly take-all. When three successive crops of winter wheat are grown at Rothamsted, for example, yields may fall from over 50 to below 20 cwt of grain/acre, despite generous use of fertilisers. Indeed, the total grain from three such crops is usually less than can be obtained from two with one of beans interpolated. By contrast, although a third successive crop of barley also had more plants with take-all than one preceded by beans, provided it was given enough nitrogen, it yielded the same amount of grain. After beans only 34 lb N/acre was needed to produce 2 tons of grain/acre, and giving more depressed the yield; to get 2 tons from the successive barley crop required 100 lb N/acre.

Considered on their own, bean crops are not financially attractive, but is it reasonable to consider them on their own? Clearly to a farmer who wants to grow barley there is nothing to be said for introducing a bean crop in his cropping sequence when its value to the succeeding barley crop can be compensated for at the cost of 66 lb N/acre. But things are different for the many who are growing barley on some of their fields only because they dare not grow wheat. It may be nationally desirable to increase our production of protein and it could be profitable to individual farmers to forget their prejudices against beans and reintroduce them into a rotation with wheat, because winter wheat is potentially more productive than barley on heavy soils, and the total value of the beans and the succeeding wheat crop grown on such land might well exceed that of two barley crops. It would ease management by spreading farm work, while not requiring any additional machines. Remembrances of past failures from aphis attack need now raise no fears, when aphids are readily controlled by a single spray with insecticides; nor need the crop any longer be dirty or call for much labour for cleaning, because weeds can be controlled by herbicides. It is unlikely that beans will regain their past importance, but their present neglect suggests that their potentialities in modern conditions of farming are going unappreciated.

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Crop physiology. To grow, plants need to be supplied with radiant energy, carbon dioxide, water and mineral nutrients, and the rate they grow depends on the temperature. The amount of dry matter they contain is the difference between the amount they produce by photosynthesis and the amount they use in growing, less any amount they may lose through the depredations of pests and diseases. The useful yield of crop plants is the amount of dry matter suitable as food for people or stock. The considerable increases in yields in recent years reflects increased supplies of nutrient, the use of irrigation, earlier sowing, which increases the period of photosynthesis, smaller losses to pests and diseases and new varieties that divert more of their synthesis into the harvested product. These broad principles are easily stated in simple terms, but underlying them, as is abundantly evident from the work we describe on crop physiology and agricultural meteorology, there are many interacting factors and a wealth of phenomena yet to be fully disclosed.

These phenomena promise to be rich not only in scientific interest but also in their practical implications. Indeed, until much more is known about the factors that limit the productivity of pathogen-free crops when adequately fed and watered, it will remain uncertain whether the potential yields of current varieties are near the maximum possible when grown as field crops, or what methods are most likely to increase yielding capacity. It is with the ultimate aim of identifying and removing these limiting factors that we make detailed measurements of the physical conditions within crops and analyse the growth of different species and different varieties in a range of environments. The meteorological measurements concerned with evapo-transpiration have already more than justified themselves practically by providing a sound basis for assessing irrigation needs; it would probably be vain to expect such immediate benefits from measurements of the energy used in photosynthesis and of changes in carbon dioxide concentration, but these also promise much of value in combination with physiological studies.

The rooms in which plants can be grown in controlled environments were in full use during the year, when for the first time we were able to study the effect on plant growth of changing one feature of the environment while keeping others constant. They were mostly used to study effects of changing temperature and humidity. Although humidity is widely thought to have little effect, and to be mainly important in determining infection by pathogens, the three crop plants tested, wheat, sugar beet and kale, were all responsive to changes, but by different amounts.

Work with pesticides. Work of many kinds with pesticides is reported by several departments. Despite its seeming diversity, ranging from field tests of the ability of various chemicals, formulated and applied in different ways, to control a range of crop pests, through studies of their effects on other organisms than pests, to the biochemical processes underlying insecticidal action and the relation between chemical structure and toxicity, it all has the same ultimate aim: to increase the efficacy of pesticides while decreasing the risk of unwanted side effects. We describe some progress in seeking an alternative for the control of wireworms to the now widely

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used chlorinated hydrocarbons, which not only persist unduly long in soil but also kill or accumulate in earthworms and other soil-inhabiting animals, in which they may reach amounts harmful to birds that chance to eat such contaminated animals. Yields of wheat in a wireworm-infested field were increased substantially by some organo-phosphorus compounds, most of which are much less persistent than the chlorinated hydrocarbons and so will affect fewer of the soil organisms, but more work will be needed to know whether these compounds can be commercially successful.

Applying systemic insecticides to seed or to the soil at planting time has several advantages. It protects plants from damage when they are too small to be sprayed efficiently, a stage when they are often especially vulnerable to attack, and largely restricts the insecticidal action to crop pests; by sparing species that prey on pests and might be killed by spraying the crop, it elicits rather than prohibits any benefits from biological control of pests. Our series of experiments, ended in 1963, on the control of potato virus diseases by insecticides, illustrates its advantages. Spraying with suitable insecticides can prolong the useful life of potato stocks in south-east England, but the same results can be achieved more simply and cheaply by applying systemic insecticides to the seed tubers or in the furrows at time of planting. Potatoes are at greatest risk of infection from aphids that arrive early in the season, sometimes even before all the plants are well above ground, so the earliest possible spraying is not always effective. Treating the seed or applying the insecticide in the furrows protects the growing plants from aphids through most of the critical period, and by doing so almost prevents the spread of leaf roll and usually considerably decreases the spread of severe mosaic. Treating bean seeds with systemic insecticides has also kept the subsequent crops free from aphids for long periods. Although the effect from treating sugar-beet seed is much briefer, it lasts long enough to be valuable with summer-sown stecklings. Growers have been quick to appreciate this, and most seed sown in steckling beds was so treated in 1963, but it would be rash to assume that this was responsible for the incidence of yellows in stecklings being the smallest ever recorded.

The nature and behaviour of the potent insecticidal substances in pyrethrum flowers have long been prominent in our research programme. Prime among their desirable properties is that, although lethal to many insect species, they are harmless to mammals, but additional valuable features are their ability to affect insects quickly ("rapid knock-down") and that there have been few examples yet of pests becoming resistant to their action. Their disadvantages are that they are unstable and, being products of specially grown plants, are scarce and expensive. Past attempts to find synthetic substitutes with their desirable qualities have met with little success. However, our work on the relation between constitution and toxicity suggested that some new compounds related to the natural pyrethrins might be valuable insecticides and also more stable. Work on these is now being supported financially by the National Research Development Corporation.

Of the 35 samples of bees received in 1963 as suspected of having been

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poisoned by insecticides, 20 contained organo-phosphates, 9 chlorinated hydrocarbons and 1 a carbamate.

Bee behaviour. Other work with bees was less macabre than the diagnosis of poisoning and provided much new information about the activities of queen bees and how the social life of colonies is organised. Many activities depend on the substances produced and secreted by the queen's mandibular glands, and increasingly these substances are being identified chemically and their biological significance demonstrated. The odour of one such substance, 9-hydroxydec-2-enoic acid, keeps swarms together and will stabilise a queenless cluster that otherwise would soon disintegrate. The odour of another substance, yet to be identified, attracts workers to the queen, but the hydroxydecenoic acid does attract drones. So, too, does 9-oxodecenoic acid, previously identified as a main component of "queen substance", which inhibits the ovaries of worker bees from developing. These two seem the only sex attractants; no evidence was obtained to support the widely held idea that queens can attract drones over distances of miles to windward, but on suitable days the substances ensure that a nubile queen soon has many drones in attendance.

The source of "queen piping", long a controversial subject, was shown to lie in wing vibration and not in the emission of air through the spiracles.

Observations on the foraging behaviour of bees shows that the distribution of hives and pollinator varieties in fruit orchards is not always such as to ensure the best set of fruit; to ensure even pollination, hives should be dispersed throughout orchards, with not more than four in one group.

Sacbrood, which seems to have been wrongly diagnosed and to be much commoner than previously thought, was found to be caused by a virus morphologically resembling the one causing paralysis, but it did not infect adult bees, and bee paralysis virus did not infect larvae.

The cause of farmer's lung. The conditions in which hay moulds so that it can cause lung disorders in men and cattle were defined last year, when it was concluded that the results pointed to thermophilic actinomycetes being responsible. This conclusion was confirmed, and the main causes were identified as *Thermopolyspora polyspora* and *Micromonospora vulgaris*. Pure cultures of *T. polyspora*, grown on sterilised hay made alkaline or on nutrient agar, not only reacted specifically with the serum of sufferers from farmer's lung but also produced typical symptoms when inhaled. Bagassosis, a common complaint of people working in sugar-cane mills, may also have the same or a similar cause, for samples of bagasse contained many of the thermophilic organisms that occur in mouldy hay.

The subjects selected for comment here fall far short of summarising the contents of the departmental reports and articles that follow, for they are regrettably few out of many, but they may serve as an introduction and do something to indicate the range of our work.

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