ROTHAMSTED RESEARCH

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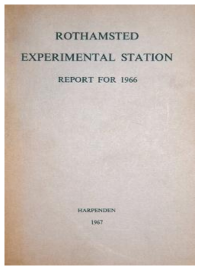
Full Table of Content



General Report

F. C. Bawden

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GENERAL REPORT

F. C. BAWDEN

Regrettably we have to record the loss of unusually many members of the staff. Susan Burlingham's death at the tragically young age of 29, after an illness borne with remarkable fortitude, robbed us of an admirable colleague and microbiology of a devoted and able worker. To W. Groom, who also died, we owe a debt of gratitude for his excellent services as head painter.

Seven members retired: D. A. Osmond from the Soil Survey; A. E. Hall, T. J. Bishop and G. F. Hanson from the Maintenance Staff; Jessie Walker from the Physics Department; Lina Cunow from the Plant Pathology Department; T. W. Barnes from Woburn. To all, we are grateful for what they did during their many years with us.

Also to be recorded is the retirement of G. V. Jacks from the Soil Bureau; although not a member of our staff, he has worked closely with us for more than 40 years, and we have benefited much from his great knowledge and wisdom. He was succeeded as Director of the Bureau by W. D. Brind, previously Assistant Director.

K. E. Clare, from the Road Research Laboratory, was appointed to succeed D. A. Osmond as Head of the Soil Survey of England and Wales, and F. E. Hearn to succeed A. E. Hall as Head of the Maintenance Staff.

Honours and awards. J. R. Moffatt was honoured by being made an Officer of the Order of the British Empire in the Birthday Honours. B. Kassanis was elected a Fellow of the Royal Society and F. Yates was awarded a Royal Medal of the Society. H. L. Penman received the Hugh Robert Mill Medal of the Royal Meteorological Society. F. C. Bawden was elected an honorary life member of the Association of Applied Biologists and of the Indian Phytopathological Society.

Visitors and visits. We received four Visiting Groups from the Agricultural Research Council, two to the departments at Rothamsted, one to the farms at Rothamsted and Woburn, and one to Broom's Barn. We are grateful to the following lady and gentlemen for giving of their time to consider our current work and future programme: Professor Helen K. Porter, F.R.S., Professor P. W. Brian, F.R.S., Professor A. H. Bunting, Professor F. C. Happold, Professor J. L. Harley, F.R.S., Professor R. D. Haworth, F.R.S., Professor Sir Joseph Hutchinson, F.R.S., Mr. J. G. Jenkins, Professor D. G. Kendall, F.R.S., Mr. G. E. Limb, Mr. D. G. Pearce, Mr. J. E. Pheysey, Professor O. W. Richards, F.R.S., Mr. Oswald Rose, Professor P. A. Sheppard, F.R.S., Professor A. R. J. P. Ubbelohde, F.R.S., Mr. R. H. Watherston, Professor J. H. Western and Professor Sir Vincent Wigglesworth, F.R.S.

Our largest single party of visitors was for the Annual General Meeting of the Association of Applied Biologists. Of the more than 3,000 visitors

https://doi.org/10.23637/ERADOC-1-14

of whom we have record, two-thirds came in organised parties and 1,000 as individuals, of whom half were from overseas. Visitors from this country included the Rt. Hon. Mr. A. E. Oram, M.P., Parliamentary Secretary to the Overseas Development Ministry, and from overseas the Minister of Agriculture of Togo and the Minister for De-centralisation, New South Wales.

The several hundred visitors to Broom's Barn included the Hungarian Deputy Minister of Agriculture and the Ambassador of the Federal Republic of Germany.

The International Congress of Microbiology in Moscow was the main occasion for members of staff travelling overseas, but was far from the only one, as will be evident from the departmental reports, which also show that we are being increasingly involved in projects of the International Biological Programme. In addition to visits recorded in the reports, F. C. Bawden attended a meeting of the Advisory Committee for the Faculty of Agriculture, University of the West Indies, and a meeting of the Agricultural Research Council of Central Africa in Zambia.

The condition of crops. The year began with land work much behind schedule, with only a small area of wheat drilled, much land unploughed, and some potatoes and sugar beet still to be harvested. However, some favourable weather in January and a fine March allowed good progress to be made and, except for four experiments planned with winter wheat, the large programme of field experiments was completed.

In the cool, wet summer (each month from April to August had more than average rain and, excepting May, less than average sunshine), irrigation systems were needed only briefly, but their use showed that watering at a critical time prevented wheat on the light land at Woburn from developing the condition we know as "scorch" and confirmed its ability to control common scab of potatoes.

A fine spell allowed some excellent hay to be made in early June, but later cuts were damaged by rain.

Barley crops were uneven at first, possibly because nitrogen was leached unevenly from the soil, but later all cereal crops grew vigorously and some barley lodged in July. Wheat and barley ripened slowly, but were harvested in good conditions, and yields and quality were both better than in 1965. The largest yield of wheat at Rothamsted (63 cwt/acre) was on the ley–arable experiment, in which the rotation of crops is designed to avoid the most damaging soil-borne pathogens, and exceeded the average yield by about 1 ton/acre. Varieties of winter wheat sown late yielded only little more than spring varieties. Some late-sown crops, especially on the less fertile fields, were greatly damaged by wheat-bulb fly. Even after fallow, losses from this pest were avoided at Rothamsted by early sowing: on land where the fly was prevented from laying, yield was 48 cwt, only 0·6 cwt more than on unprotected land drilled early in November, but 10 cwt more than on unprotected land drilled in January. Lasting damage was done only to crops that had not started to tiller when they were attacked in spring. However, early sowing seems not to be a safeguard everywhere, and at Saxmundham wheat sown in October was too damaged to yield

https://doi.org/10.23637/ERADOC-1-14

well. It is fortunate, therefore, that the search for a seed dressing to replace the chlorinated hydrocarbons is showing promise of success, for in soils where 80% of the shoots from untreated seed were attacked by wheat-bulb fly only 12–20% of the shoots were attacked from seeds treated with carbophenothion.

Unlike our experience in 1964 and 1965 at Rothamsted, where slit-seeding wheat into unploughed land sprayed with paraquat gave very poor crops because grassy weeds survived, on the lighter land at Woburn, this treatment gave a good crop of spring wheat yielding as much (45 cwt/acre) as on plots ploughed and cultivated traditionally. Treating the soil with a mixture of insecticides increased yields on both ploughed and unploughed land.

Spraying spring wheat with the dwarfing compound CCC (2-chloroethyltrimethyl-ammonium chloride) again increased yield at Rothamsted by 2 cwt/acre and at Woburn it did so by 6 cwt. The unsprayed plots did not lodge, so the increased yield did not come from preventing lodging. At Woburn spraying was tested with and without irrigation. Irrigation increased yield by 10 cwt/acre, had less effect on the sprayed plots and CCC did not increase the yield on irrigated plots.

Barley also yielded more in the ley–arable experiments than elsewhere, with the maximum yield, 61 cwt/acre, exceeding the average by more than 1 ton. Unlike winter wheat, which consistently gives equal yields whether the seed is broadcast or drilled in rows 7 in. or 4 in. apart, barley sometimes yields more when drilled than when broadcast and more at 4-in. than at 7-in. spacing. However, with both crops, methods of sowing are much less important than the seeding rate and the amount of nitrogen fertiliser. On our fields, sowing 140 lb/acre consistently gives a bigger yield of wheat than sowing 240 lb; this is also true of barley when drilled, but when broadcast the larger amount of seed gives the bigger yield.

The weather suited potatoes, and despite attacks of blight they yielded well, averaging around 20 tons/acre total tubers, with some plots giving 27 tons/acre. This was the first year when we had enough of the clone of King Edward we freed from paracrinkle virus to grow in field experiments, and it is unlikely to be a coincidence that it was also the first occasion that King Edward yielded better than Majestic where the two were compared. Some late-planted crops emerged slowly because of "coiled sprout", a condition that was encouraged by chitting the seed, planting it deeply and compacting the soil. A so far inexplicable result was that potatoes on the site of the old continuous wheat and barley experiments at Woburn yielded nearly twice as much on the land where barley was long grown (average 12·7 tons/acre) as where wheat was grown (average 7·4 tons/acre). Several of the crops at Woburn died early because of infection with *Verticillium* sp. Pentland Dell grown at Woburn developed "spraing", showing the presence there of tobacco rattle virus, and its eelworm vector was found in the soil.

It is our practice now to grow our own potato seed for use in experiments, produced from Stock Seed grown away from other potatoes and treated with insecticides to check the spread of aphid-transmitted viruses. All our seed could not be lifted in the wet autumn of 1965, and so we had

https://doi.org/10.23637/ERADOC-1-14

to buy some. The value of our practice was amply demonstrated by the better stands from our own seed. The Stock Seed from Scotland was not only severely bruised but had much skin spot and gangrene, and gave very gappy crops. Our survey of the health of seed tubers shows that we were not exceptional in being sold such seed, for skin spot was prevalent in all the stocks we examined and gangrene in very many.

Although the stunting of young beet known as "Docking disorder" was generally less prevalent than in 1964 or 1965, it was noted at Woburn for the first time, and species of the eelworms *Longidorus* and *Trichodorus* were found in the land where the beet were affected. Some plants were also infected with beet ringspot virus, which is transmitted by *Longidorus elongatus*. In contrast to "Docking disorder", beet yellows was more prevalent than in any year since 1961, for after the mild winter aphids were active early. Spray warnings were issued to several areas in June, and nearly 300,000 acres of the crop were sprayed. This, and the fact that there are now fewer over-wintering sources of the virus than previously, kept the incidence well below what it used to be in similar seasons. However, there were more than 30,000 acres with more than 20% plants infected, which meant considerable loss of yield, either because growers were not using recommended control measures or because these measures are not fully effective. On average of three trials, treating the seed with "Nemagon" increased yield of roots by 1 ton/acre, and there was no extra increase from spraying the crop with insecticide. In another wet autumn sugar-beet lifting was again troublesome and trying, but happily was finished by the end of the year.

The aphid vector of carrot motley dwarf was also active early; checking its activities, either by adding menazon granules to the soil at sowing time or by spraying the crop during June and July, increased yield of marketable roots by 3–5 tons/acre.

Only spring beans were grown and these grew vigorously in the wet summer. Despite a late harvest and losses of at least 5 cwt/acre from shed grain, yields were considerably larger than usual, several exceeding 2 tons/acre. Since we achieved the control of black aphids many years ago, we have consistently worked with beans and have advocated their use as a very valuable break crop for the cereal grower. It seems our advice is now being accepted, because this year there were many more bean crops than previously. We hope others also had such good yields and regret we cannot tell them how to do so regularly, though if they keep their soil near neutral, give enough potash and phosphate, use a systemic insecticide and arrange for enough water, our experience is that there will be a reasonable crop. Even though they get less than 2 tons/acre, at least they will know that a succeeding wheat crop will do much better than it otherwise would have, and will do it with much less nitrogen.

Changes in the Classical Experiments. Continuing our policy of modifying the Classical Experiments to give new information and information more relevant to modern farming practice, we describe changes to be made in Broadbalk, Hoosfield Permanent Barley and Barnfield sites, where only one type of crop has been grown for more than 100 years. Although

https://doi.org/10.23637/ERADOC-1-14

yields of wheat on some plots of Broadbalk and of barley on some plots of Hoosfield are sometimes as much as the national average, they are only half as much as obtained on other of our experiments, presumably because of the soil-borne diseases known to be present. The major change will be to introduce new crops, but the manuring of some plots will be modified, and new varieties of the traditional crops will be grown. On Broadbalk, for example, the sections at the top and bottom of the field will continue to grow only winter wheat, with an occasional fallow should perennial weeds make this necessary, but the variety Capelle will replace Squarehead's Master. The three middle sections will grow three crops in rotation, potatoes, spring beans and Cappelle wheat. This will not only show how these other two crops behave on plots that differ greatly in fertility from the accumulated effects of differences in past manuring but, more important, will show how wheat behaves when less affected than now by soil-borne diseases. The top and bottom sections will retain continuity with the past, and comparing the yields on these with those of wheat on similarly treated plots in the three middle sections will show the effects of a crop rotation over a wide range of manurial treatments.

Similarly, on Hoosfield some plots will be retained growing spring barley continuously, and others will grow potatoes, beans and barley in rotation. A rotation of crops will also be introduced on Barnfield, but its future has not yet been decided in detail. An obviously desirable subject to study on land that has not carried a cereal crop since 1855 will be the development there of soil-borne diseases of cereals. The most important soil-borne pathogens on Broadbalk and Hoosfield are the fungi causing take-all and eyespot, but a survey for *Fusarium* sp. showed large populations of *F. roseum* "Culmorum", especially on the plots given most nitrogen; populations in Barnfield soil were very small.

The changes made to some plots on the Park Grass experiment in 1964 are producing effects; liming the previously acid plots has changed their vigour, but without yet changing the relative abundance of different species on the plots. Giving extra nitrogen has greatly increased yields, but with the largest dressing there is now much bare ground. Similar dressings on nearby grazed pasture have not had such an effect, and on Park Grass the same total amount of nitrogen applied in smaller amounts was less damaging.

The need for soil disinfection. Again we report examples of considerable increases in crop yields, especially on light soil, from treating land with disinfectants, either fungicides or nematicides. Many pests are encouraged by frequent growing of the same crop, and the damage they do can be lessened by suitable crop rotations. However, farmers are becoming increasingly specialised, and those mainly engaged in growing cereals cannot readily change their cropping. Also, not all soil-borne pathogens are kept in check by traditional crop rotations, because they have large host ranges. For instance, although growing beet not more than once in three years safeguards against damage by the beet cyst-eelworm, it does not against the free-living eelworms that cause Docking disorder. Indeed, these eelworms seem to be more encouraged by barley and leys than by beet, and beet after beet might well suffer less than beet after barley.

https://doi.org/10.23637/ERADOC-1-14

At present our experiments on soil disinfection indicate the size of current losses rather than demonstrate practical ways of increasing yield, for although the treatments we are using are reasonably effective, their cost is too large for arable crops to bear, and the benefits from some last for only one season. In time the plant breeder may solve the problem by producing crop varieties resistant to the common soil-borne pathogens, as he has to potato cyst-eelworm. By growing resistant and susceptible varieties alternately, potatoes can now be grown on lightly infested land more often than previously without suffering greatly from this pest or risking the rapid increase of forms of the pest able to multiply in the resistant variety. However, there is no possibility yet to be seen of varieties of other crops resistant to other soil-borne pathogens that are prevalent in so much of our arable land. These are not only keeping yields of many crops less than they otherwise would be but lead to waste of fertilisers that are applied to, but cannot be used fully by, plants whose roots are damaged. Only a direct attack on these pathogens seems likely to achieve results, and urgently needed is a partial sterilant cheap enough to apply to soil or, more desirable but probably even less likely to be achieved soon, systemic pesticides that when sprayed on to young crops will kill pathogens attacking their roots. Some progress was made in cheapening the control of the eelworm causing Docking disorder, for considerable benefit was obtained when the nematicide "D-D" was applied in small amounts to the bottom of the plough furrow instead of injecting the usual 400 lb/acre.

A potato virus transmitted by a fungus. A previously undescribed virus ("mop-top") was found last year in stocks of several potato varieties, in some of which the symptoms included lesions in the flesh of the tubers, somewhat resembling "spraing" caused by another soil-borne virus, tobacco rattle. Its prevalence now becomes explicable with the discovery that it is transmitted by the powdery scab fungus *Spongospora subterranea*, which the survey of fungi attacking seed tubers showed to be present in three-quarters of the commercial stocks examined.

The techniques of apical-meristem culture, which produced the clone of King Edward free from paracrinkle virus, was applied successfully to produce virus-free clones of five varieties, of which all current stocks are virus-infected: Golden Wonder was freed from potato virus A; Arran Comet from virus X; Epicure, Orion and Sharpes Express from virus S.

Our work with various viruses affecting leguminous plants suggests that, like lucerne, perennial clovers may be important sources of infection for beans and peas. The viruses found in clovers include one that is distantly related to potato virus S, one to potato virus X and one to potato virus Y, but we have no evidence that any of these variants infects potato plants.

A potent new insecticide. Last year we described the synthesis of compounds with equal or greater insecticidal activity than the natural pyrethrins. Further variation in the basic structure deduced to be necessary for activity has given compounds of much greater potency, while still retaining the desirable features of the natural pyrethrins such as rapid

https://doi.org/10.23637/ERADOC-1-14

"knock-down" of insects and being almost harmless to mammals. Outstanding among these is 5-benzyl-3-furylmethyl (+)-*trans*-chrysanthemate, which is 55 times more toxic to houseflies and 10 times more toxic to mustard beetles than are the mixed esters of natural pyrethrins. It is several times as toxic to both these insects as the organophosphorus insecticides parathion and diazinon, and the (±)-*cis–trans*-chrysanthemate is more toxic than any other known compound to *Anopheles* mosquitoes. Such insecticidal activity is unique among compounds containing only carbon, hydrogen and oxygen. These compounds are protected by patents assigned to the National Research Development Corporation.

We also report much work with organophosphorus insecticides, on the way they act, on the mechanism and inheritance of resistance to their action, their movement in soil, their uptake by plants and their use to control various specific pests. The search for materials to replace the persistent chlorinated hydrocarbons is proving more difficult for the control of wireworms than for the control of wheat-bulb fly.

Only 31 samples of bees were received suspected of being poisoned by insecticides, fewer than half the number received in 1965. Of these only 20 contained insecticide, 12 organophosphates. The commonest cause of bees being poisoned is the spraying of bean crops. Granular insecticides are as effective as sprays in controlling bean aphid, and their use would avoid this risk to bees.

Computation. The demand for computation grows rapidly, and since the Orion was installed the number of experiments analysed has more than doubled and the number of variates almost trebled. The demand has been met only because the capabilities of the installation were increased, first, by replacing the flexowriter with a speedy line-printer, and second, by the fortunate event that the Rutherford Laboratory has replaced its Orion, and we obtained from them as many drums, tape decks and other parts as we could accommodate. To help with the considerable amount of work we do for other countries, the Overseas Department Ministry provided an extra post in the Statistics Department. Many new programmes were written and some old ones improved. Surveys of fertiliser practice and several other subjects were analysed.

Fertiliser use. The 1966 survey of fertiliser practice shows no very new trends. The amount of nitrogen used for cereals and temporary leys continues to increase at about the same rate as between 1957 and 1962 in the eastern part of England, but more slowly elsewhere, whereas the amount of phosphate and potash remains near constant. Permanent pasture, our largest national acreage, still receives very little nitrogen, and very little more than it did four years ago, although, as our experiments abundantly show, it responds greatly to it. This presumably means that pastoralists are relying on nitrogen fixed by clovers, but there is little evidence that they are doing much to increase the clover, for less phosphate was used on permanent pastures than previously. The contrast between the treatment given to temporary leys and to permanent pasture is striking, for the amount of nitrogen given to leys has increased greatly, and on

https://doi.org/10.23637/ERADOC-1-14

average leys now receive as much as barley. However, they are getting less potash, and although grazed leys may be getting enough, there is the possibility that leys that are cut may be removing more potash than the crops are being given. The neglect of permanent pasture may reflect the small profit from producing cattle and sheep, but this is not the only reason, because dairy farmers seem to treat their permanent pasture no more generously. Even on the intensive dairy farms of Cheshire and Lancashire, only about a half of the permanent pasture received any nitrogen, and to these fields the average amount given was less than half as much as was given to leys.

Anhydrous ammonia, which is widely used as a fertiliser in the United States of America, is now being marketed in the United Kingdom. In our tests it was equally as effective as "Nitro-Chalk" for wheat when used at around 1 cwt N/acre, though less so at 0·5 cwt/acre, but it was much less effective for grass on the stony Rothamsted soil, which was not penetrated deeply enough by the injector for the slits to be fully sealed, and some ammonia was lost.

The advantages from the cheapness of urea as a nitrogen fertiliser can be offset by the fact that it often damages seedlings, as it did in further of our tests this year, and that on some soils it decomposes quickly and ammonia is lost to the air. Urea-phosphate was free from these defects, and at Rothamsted was as effective a nitrogen fertiliser as ammonium nitrate for wheat and grass and slightly more effective on the light soil at Woburn.

The results of many of our cereal experiments again emphasise the need, for optimal use of nitrogen fertilisers, to consider the history of the field, not only past cropping and manuring but also leaching by rain and the likely incidence of soil-borne pests and diseases. Not to do so, and to give a standard amount, means that sometimes the yield is much less than it could be, and at others fertiliser is not only wasted but will lessen yields by causing the crop to lodge.

The optimal use of nitrogen fertilisers is only one out of many lines of work on crop nutrition and soil fertility described in the later sections of the Report, but the others must go without comment here; as also must most of our work on many other subjects, ranging from aphrodisiacs for bees to X-ray crystallography of phlogopite.

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