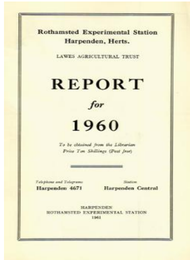
ROTHAMSTED RESEARCH

Report for 1960

Full Table of Content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General Report

F. C. Bawden

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GENERAL REPORT

F. C. Bawden

H. F. Barnes, whose exceptionally productive work over 33 years did so much to establish the high reputation enjoyed by our Entomology Department, died suddenly in February. He was rightly known the world over as the authority on gall midges, but Barnes was no narrow specialist. Indeed, he was an excellent natural historian, and as evidence of his width of interest there is no need to cite more than his admirable work on slugs. Immensely industrious, and with an infinite capacity for taking pains to ensure the reliability of his conclusions, he was oblivious of normal working hours; when midges were active by day and slugs by night, most of the 24 hours were happily spent shrewdly observing these very different kinds of animals, whose behaviour and importance he did so much to elucidate. We mourn the loss, not only of an irreplaceable fund of knowledge but of an unique personality and an unusually loyal colleague, selflessly devoted to his work and to Rothamsted.

We also sadly report the death in June of R. K. Schofield, Reader in Soil Science at Oxford University, but a member of the Rothamsted staff for 28 years, during which he was head of the Physics Department for eight and of the Chemistry Department for two, in itself a testimonial to his versatility. A man of great originality and acute insight, his many novel ideas will long continue to influence the development of soil science. We shall miss his scientific inspiration, but shall also miss him because there will be no more of those delightful summer evenings when he played for us so tunefully and led us so ably and charmingly in country dancing on the Manor House lawn.

Fortunately, June also had its bright side. It brought the good news that Mary D. Glynne had been awarded the O.B.E., a welcome public acknowledgement of her many and varied contributions to agriculture and plant pathology during her 33 years at Rothamsted. H. G. Thornton, who retired in 1957 from the post of head of the Soil Microbiology Department, was made a Knight Bachelor in the same Honours List. 1960 was unusual in having a third Honours List, and the last day of the year was cheered by the news that W. C. Game's valued services for 50 years had been recognised by the award of the British Empire Medal.

C. G. Johnson's outstanding research gained him a special (" merit ") promotion to the grade of Senior Principal Scientific Officer. F. Yates was awarded the Guy Medal in Gold of the Royal Statistical Society. F. C. Bawden was elected an Honorary Life Member of the Indian Botanical Society.

The Agricultural Research Council Unit of Plant Morphogenesis and Nutrition moved to Wye College, and we wish Dr. F. J. Richards and his colleagues well in their new home. As this unit they had been with us for only two years, but as the Research Institute of Plant Physiology they have worked at Rothamsted since 1917, and we regret ending such a long, friendly and profitable association. We can make good use of the laboratories they vacated, but we would have preferred other ways of alleviating our overcrowding.

We have many plans to this end and for improving our glasshouses and other facilities, but unfortunately have few achievements to report. However, at the end of the year builders were on the site where there will be a small additional building to house some of our statisticians and a new Orion computer, which has been ordered and is promised for delivery late in 1962. It will not be too soon, for although the growing demands for computations were still met this year, our present machine gave much trouble, and a faster one, more versatile and easier to programme, is urgently needed to cope with analyses of surveys and the ever-increasing range of problems requiring complex analyses and computations.

Considerable progress was made in developing Broom's Barn, where a bore-hole was sunk successfully, roads were laid and the site prepared for laboratories and other buildings, for which tenders will soon be sought.

Visitors and visits

Prime among our several thousands of visitors were six " Visiting Groups " from the Agricultural Research Council. We thank the following gentlemen for giving of their valuable time to consider our affairs: Professor A. C. Aitken, F.R.S., Professor R. M. Barrer, F.R.S., Professor T. A. Bennet-Clark, F.R.S., Dr. A. S. Douglas, Dr. E. F. Gale, F.R.S., Professor Sir Joseph Hutchinson, C.M.G., F.R.S., Professor W. O. James, F.R.S., Professor Sir Hans Krebs, F.R.S., Professor O. W. Richards, F.R.S., Dr. K. M. Smith, C.B.E., F.R.S., Sir Geoffrey Taylor, F.R.S., Professor R. L. Wain, F.R.S., Professor C. W. Wardlaw, Professor V. B. Wigglesworth, C.B.E., F.R.S.

Of parties from overseas, the largest were four of delegates attending the Eighth International Grassland Conference; others included the Agricultural Committee of the Council of Europe, the European Barley Committee, the Commonwealth Entomological Conference, the Commonwealth Mycological Conference, delegates to the Tercentenary Celebrations of the Royal Society, to the Commonwealth Bureaux Review Conference and to the Second International Youth Science Fortnight. Individual visitors included the Ministers of Agriculture for Ceylon (Hon. C. P. de Silva), Eastern Nigeria (Mr. P. N. Okeke), Malaya (Hon. Inche Abdul Aziz bin Ishak), and Victoria, Australia (Hon. G. L. Chandler, C.M.G.) and the Minister of Natural Resources, British Guiana (Mr. B. Benn).

The many parties from the United Kingdom included the Nutrition Society and the Society of Applied Bacteriology. On 13 May the Rt. Hon. John Hare, M.P., then Minister of Agriculture, took luncheon in the Manor House with several other notabilities before formally opening the Ministry of Agriculture Plant Pathology Laboratory at Hatching Green.

Many of the staff travelled overseas, some to attend international congresses, others in response to requests from many different countries for advisory visits or for help with specific research or development projects. We do our best to meet such requests, but they are now so frequent that regretfully most have to be refused.

The weather and crops

There was more rain than in any year since 1927, with the total at Rothamsted nearly 8 inches above the long-period mean. However, it was not uniformly distributed, and the first and second six months differed strikingly. The year started with field work unusually well forward, and the spring and early summer also favoured crops and farm operations. Indeed, the only problem was a shortage of grass from lack of rain during March to June, when we got 2·5 inches fewer than the long-period mean. Until the end of June conditions looked like rivalling those in 1959, with the promise of another early and easy harvest. The promise was fulfilled only with hay, of which an excellent crop was harvested early and without difficulty. July, August and September all had above average rain, and the cereal harvest was slow and difficult; many crops lodged, some sprouted in the ear, and our grain drier was taxed to capacity. Nevertheless, some plots yielded well; despite lodging, winter wheat sown early after potatoes yielded over 50 cwt./acre, nearly 20 cwt. more than when otherwise treated similarly but coming after another wheat crop.

Bad as conditions were for the cereal harvest, they later became worse. October, November and December produced over 8 inches of rain more than the long-period mean, and there were only 11 days on which less than 0·01 inches of rain fell. The year ended with many acres of potatoes still in water-logged ground, most fields still unploughed, only one lot of winter wheat drilled at Rothamsted and none at Woburn or Broom's Barn.

The contrasting weather of the first and second halves of the year was reflected in an unusual mixture of pests and diseases, for the first half gave us those usually prevalent in dry years and the second those usually prevalent in wet years. Some aphid species were active early in the year, and viruses spread rapidly in many early-sown crops of various kinds, and it seemed that the sugar-beet crop was again threatened by an early and severe attack of yellows. Fortunately this did not fully materialise, for predators of aphids were also plentiful in many places, which helped to check the infestation, and the weather from July onwards did not favour aphids. Nevertheless, there was again need to issue spray warnings, and most of the crops in south-east England were sprayed at least once. Perhaps significantly, yellows was much less prevalent in the south-east, which before crops were sprayed was always the worst affected area, than in the north and west. Experiments at Rothamsted and Broom's Barn again showed considerable benefit from spraying, though less than in 1959, when aphids were more numerous and active. A single well-timed spray increased yield of roots by over 2·5 tons/acre; at Broom's Barn two sprays were profitable, for unsprayed plots gave 36 cwt. of sugar per acre, and those sprayed once about 47 cwt., whereas those sprayed twice gave 52 cwt. The national average yield per acre is the highest ever recorded, but the wet weather that helped to produce this record crop also made its harvesting an appalling task, still unfinished at the end of the year.

The continuous wet weather also produced some exceptional crops of potatoes, up to 26 tons of tubers per acre in some experiments at Rothamsted and an average of 21 tons with the variety Ulster Supreme at Woburn. And this despite an unusually severe attack of blight. Conditions so continuously favoured the spread of the fungus that spraying did not prevent blight, although it did prolong the life of the tops enough to increase yields by up to 4 tons of tubers per acre, the largest response to spraying we have recorded. A tin compound that showed promise against potato blight in the less testing conditions in 1959 again prolonged the life of the tops and increased tuber yields more than did copper or zinc fungicides. The tin compound was also effective against downy mildew in sugar-beet steckling beds. A high proportion of the tubers set by some potato varieties (more than a quarter of the King Edward crop) became infected by the blight fungus. Tubers are considered usually to become infected only by spores produced on the leaves and stems, but this year the fungus may have spread underground, because it was often found sporing profusively on tubers.

Irrigation

Of the many results on the great range of subjects described in the departmental reports and abstracts of published papers, only a few can be commented on here, and it may seem odd to choose irrigation after a year so wet as 1960. However, it is appropriate, not simply because even in this year early potatoes and grass benefited from irrigation, but for the good reason that the experiment at Woburn completed its third three-year cycle of crops and reached the stage when the practical results can be assessed. The number of farmers who irrigate their crops increases steadily, and many are guided in their practice by a Ministry of Agriculture Bulletin, published in 1954 and largely based on earlier Rothamsted work. This work suggested there would be need for irrigation when the rainfall for the months April to September was 3 inches less than the potential transpiration as estimated from ordinary meteorological measurements. Past records suggested that this would happen about seven years in ten at Woburn and still more often to the south and east. Actually, only five instead of six of the nine years of the experiment satisfied the specification of " irrigation need ". Of the twenty crops taken in these five years, all but two had their yields increased by watering at times and in amounts determined by weekly estimates of potential transpiration calculated from meteorological measurements made at Woburn. Of the sixteen crops taken in the four other years, only four had their yields increased by watering, and a few had their yields decreased when early irrigation was followed by heavy summer rain that caused leaching. In general, then, the original specification of irrigation need was substantiated, but it was hardly to be expected that all crops have the same water requirements, and the specification underestimates the need for grass and potatoes, is about right for beans and overestimates the need for sugar beet and cereals. The first three crops seem to suffer from lack of water at all stages of growth, whereas cereals suffer mainly from a dry early summer and sugar beet from a dry late summer. Results with sugar beet have varied more than with other crops, and its water requirements are being studied in other more detailed experiments.

The large increases in yields of all crops in many years are evidence enough of the great potentialities irrigation has for increasing agricultural production in south-east England. Also, by showing how often benefits can be expected, when there is the need to water, how much water should be given and what benefits can be expected, the results remove the practice from the realms of guesswork and establish it on sound principles. Some uncertainties still remain. One is that watering is decided only by past weather, and irrigation will occasionally depress yields when watering is followed by heavy rain. This will not be fully overcome until weather forecasting reaches the stage of foretelling the weather for up to a week or more. This is not our problem, and meanwhile we must be content to know that the occasional depressions in yield are trivial compared with the many increases. What is our problem is that the interactions between watering and manuring differ with different crops; for example, barley yields are increased more by extra nitrogen than by extra water, and the less nitrogen it gets, the more it responds to irrigation, whereas wheat seems to need the water before it responds to extra nitrogen. Further work will doubtless explain this and show how manuring and watering should be combined to give the best results, not simply with cereals, which will probably be the last crops to be irrigated until there is a national plan to supply the south-east with abundant water, but with those that respond to watering more and more often.

The Woburn experiment more than justifies itself for its immediate value to agricultural practice, but it has value beyond this. Much of the work in the Botany and Physics Departments is done to find how plant growth and crop yields depend on the weather, and the continuing results from the irrigation experiment provide invaluable material for studying this problem.

Organic matter in soil

Our Report for 1958 stated that: " In some light soils organic matter seems necessary to maintain a structure, but at Rothamsted there is little evidence that it affects the growth of crops except through the supply of plant nutrients." This simple statement apparently disturbed some people who, to quote the editor of one journal, " fondly imagined that one of the major reasons for using organic matter on heavy soil, was to improve structure and that this was important to the well being of crops ". He then urged Rothamsted to start " some really sensible and conclusive experiments ".

Well, what is a sensible experiment can be a matter of opinion, but there is no doubt that we have been experimenting continually with organic manures longer than anyone else, and we have probably done many more experiments than anyone else to try and elucidate their beneficial effects, particularly of dung. Over a long time we have accumulated ample evidence of their value, but can only repeat that at Rothamsted there is no evidence that this extends beyond their effects on the supply of nutrients. That arable crops can be grown continually without needing any more organic matter than is supplied by their ploughed-in residues is shown clearly enough by Broadbalk, where, after 117 years of growing only wheat, Plot 8, which gets only mineral fertilisers, yields as much as Plot 2, which gets 14 tons of dung annually. Only a glance is needed to see that the soil of Plot 8 differs from the rest, and the difference is what would generally be agreed on as an improvement, but wheat apparently fails to appreciate this. Even at Woburn, where poor soil structure can present problems, the yields of barley, sugar beet, wheat and potatoes recorded in the six-course rotation experiments are higher after 30 years during which only mineral fertilisers have been used than they were at the start of the experiment. Organic matter may be necessary, but it need not be applied as manures.

There are experiments at Woburn in which yields of some crops have been increased more by dung than by the mineral fertilisers given, but how to interpret these differences is by no means sure. As reported below, dung itself is a very variable material, even in its content of the three main nutrients, nitrogen, phosphate and potash, so ensuring that these contents are accurately matched by amounts of mineral fertilisers applied requires detailed analysis of each sample of dung. Dung supplies other elements than N.P.K., such as calcium, magnesium and sodium, any or all of which may increase yields. Also dung is ploughed in, whereas mineral fertilisers are usually broadcast or drilled, so nutrients are supplied at different positions in the soil. Current work on the Market-garden and Ley–Arable experiments suggests that the greater yields produced by dung than by mineral fertilisers may be largely explained by differences between the amounts of K applied and between the positions occupied by the K when applied as dung and as mineral fertiliser. Modifications to the Market-garden experiment should show whether dung is affecting crop growth in ways other than by the nutrients it supplies.

Even with such infertile and difficult sandy soils as some of the Forest Nurseries we get no evidence that organic manures are essential, as was at one time thought; when mineral fertilisers are given so that they supply plant nutrients in the same amounts as those in composts, the Sitka spruce seedlings grow as well as with compost.

Effects of organic matter on soil structure were shown by thin sections of soils with contrasting histories and by wetting and draining them to measure their stability and their permeability. Measurements of the pores in natural aggregates of soils after long-continued arable cropping suggested that root growth might be impeded in sandy soils but not in clay soils. Dung slightly increased permeability to water and stability on wetting, but its effect on sandy Woburn soil, even after many annual applications, was slight compared with the effect produced by a period under a ley. Even the effects from a three-year ley, however, were lost a year after ploughing the Woburn soil.

Freshly added organic manures or plant residues behave very differently from the decomposed organic matter in soils. The fresh materials provide a rich source of nutrients as they decompose, and they usually improve soil structure, which may affect crop growth; but both effects are temporary. The decomposed organic matter contains plant nutrients that are released only slowly, and it lastingly modifies the physico-chemical properties of soil, but often without affecting the gross physical characters.

Soil organic matter is complex and variable, and it is vain to expect that conclusions about its effects on crop growth in one set of conditions will apply at all generally. Nor need all its effects be from its nutrient content or by changing soil structure. The quantity and quality of organic matter also largely determine the number and kind of organisms in the soil, and changes in these might well affect crop growth. That they do is obvious enough when the prevalent ones are parasitic on crops, but it is more difficult to get conclusive evidence about effects of some that are widely thought to be beneficial. Soils rich in organic matter are usually fertile soils; they also usually have high populations of organisms, including earthworms, but this does not prove that fertility depends on or is even influenced by earthworms. Such correlations may reflect cause and effect, but they are often fortuitous; organic soils could be fertile simply because they are richly endowed with plant nutrients, and the reason they contain many earthworms could be simply that the worms feed on organic matter. To get conclusive evidence is difficult, but our tests after five years on poor hill pasture still fail to show any benefits attributable to soil fauna, whereas plots treated with lime and mineral fertilisers have greatly improved during this time. However, in other conditions earthworms may affect the growth of crops, and a lack of earthworms sometimes has striking effects on unploughed soil. An apple orchard at Wisbech where copper fungicides have long been used now has few earthworms; the fallen leaves no longer get buried, and the soil is covered with a thick mat of partially decomposed leaves.

Bacterial fertilisers

Can the micro-flora of the soil be manipulated and offer better chances than the fauna of benefiting agricultural crops? To be fertile, soils must contain nitrifying bacteria, but these usually reflect the amount of nitrogen in the soil and only change its form, without adding anything to the total supply of nutrients. Can the nitrogen-fixers be usefully encouraged? Or any types of organism that may make available to plants nutrients that otherwise would remain unavailable? In Russia it seems to be accepted that this can be done by the simple process of inoculating seeds with bacterial cultures, mainly of *Azotobacter*. Many acres there are sown annually with seed treated with " bacterial fertilisers ", but few results have been published that allow the value of the treatment to be assessed critically. The preliminary experiments we report do not and could not show whether seed inoculation is of practical value, but the results are both interesting and puzzling. They show clearly that seed inoculation can produce exceedingly high populations of *Azotobacter* along the root system (rhizosphere) of plants, even though the soils in which the seeds were sown already contain the organism: for example, spring wheat from inoculated seed growing in peat soil had an average of 2,600 *Azotobacter* per gram of rhizosphere soil, whereas rhizosphere soil from uninoculated plants had only 227 and soil away from roots 171. Yields in the field experiments, however, were little influenced by the greatly different population of *Azotobacter*. In contrast, inoculation with *Azotobacter* sometimes greatly increased the growth of various kinds of plants grown in pots, but responses were unpredictable, and as often as not inoculation did not significantly affect plant growth. Failure to affect plant growth did not depend on failure of the *Azotobacter* to become established, and large populations developed in the rhizosphere of plants whose growth did not differ from that of uninoculated plants. Nor did the response depend on the amount of nitrogen in the soil; sometimes inoculation with *Azotobacter* increased yields more and sometimes less when the nitrogen content was increased. There seems no question that inoculation can stimulate plant growth, but it does so only in certain conditions, which are as yet wholly undefined and will need specifying in detail before the value of inoculation can be predicted.

Queen substance and other biologically active materials

One phase of work on " queen substance ", done in collaboration with Dr. A. K. Callow of the National Institute for Medical Research, ended successfully by establishing its identity as 9-oxodec-2-enoic acid; the analysis was confirmed by synthesising the acid and showing the synthetic product to be as active as the natural one in inhibiting ovary development in worker bees and in preventing workers from rearing new queens. Now that " queen substance " can be produced in quantity, its practical use in bee-keeping can be fully tested. Tests with the synthesised acid show that it does not attract worker bees from a distance, as a queen bee does; a second substance with this attractive power has now been extracted from queens in ethanol, and its identity is being studied. It presumably ensures that workers will visit the queen and get the queen substance that controls their behaviour.

Another successful analysis and synthesis identified all four insecticidal constituents of pyrethrum extracts as 2: 4-dinitrophenylhydrazones, so bringing cinerins I and II into line with pyrethrins I and II. The insecticidal activities of all four can be enhanced by using them with some other substances (synergists) that alone are not insecticidal; it is of some interest that the relative activities of the individual pyrethrins and cinerins differ considerably depending on whether they are used with or without a synergist.

Progress was also made towards establishing the identity of another biologically active substance, namely, the " hatching factor " that is produced by roots of potato and tomato plants and stimulates eggs of potato-root eelworm to hatch; its constitution has still to be established, but it seems to be a monobasic acid, possibly with the gross constitution represented by the formula $C_{11}H_{16}O_4$. It does not contain the lactone ring suggested by other workers. Material with similar general properties to the potato-root eelworm hatching factor, but which specifically stimulates the hatching of beet eelworm, was isolated from diffusates produced by roots of rape seedlings.

Virus research

We reported last year that the virus-free stock of King Edward VII potatoes, produced by propagation from a plant obtained by culturing on agar the excised growing point from a stem, showed promise of being more vigorous than commercial stocks, all of which are infected. The results of the first field trials, made by the National Institute of Agricultural Botany, confirmed this promise by showing that, on average, the virus-free clone yielded 10% more weight of tubers than seven of the best obtainable stocks now being grown. There is now enough of the virus-free stock to supply some to potato-seed growers, but new results with the virus show that the stock will need checking to ensure that it remains virus-free. For the more than 30 years during which paracrinkle virus had been known to be in the King Edward variety, no insect had been found to transmit it and if the virus originally had an insect vector, it seemed to have lost it. This may be true of the virus strains contained in some stocks, but it is not true of all, for those in some commercial stocks tested this year were readily transmitted by the peach-potato aphis, *Myzus persicae*. If the virus-free stock is planted near such commercial ones, there is the obvious risk that it will become infected and lose its extra cropping power.

Further work with the Rothamsted culture of tobacco necrosis virus has explained many of the puzzling features of past results with this culture and revealed a new phenomenon, that one virus may depend wholly on another for its ability to multiply. For some years we have known that extracts from infected plants always contained specific nucleoprotein particles of two sizes, and sometimes of three, but the relationships between these particles was obscure. The smallest could be crystallised, but when taken to this state preparations had little infectivity compared with that of unfractionated leaf extracts. It seemed likely that the smallest particles either lost infectivity while being separated or were non-infective material produced as a side effect when the larger ones multiply, as does happen in infections with some other viruses. However, new methods of separating the particles of different sizes have brought a different conclusion. Neither the largest nor the smallest particles are infective, and the largest consist simply of twelve of the smallest aggregated in a specific manner; plants inoculated with them show no lesions, and no virus can later be detected in them. Plants inoculated with the middle-sized particles developed lesions, and extracts from them contain only middle-sized particles. Plants inoculated with these particles plus the smallest also develop lesions, though rather different in type, and extracts from these plants also contain particles of both sizes, in proportions roughly reflecting their relative amounts in the initial inoculum. The two particles seem to be unrelated viruses, but the small ones lack some function essential to their multiplication, and this lack is made good in cells where the large ones are multiplying. This phenomenon is still known only with the Rothamsted culture of tobacco necrosis virus, which may be unique, but if it applies to some others it might go far to explain some previously inexplicable outbreaks of virus diseases.

Much other new information, not only about the behaviour and structure of viruses but also about very many other subjects unmentioned in my inadequate survey, can be found in the succeeding pages. One review of the Report for 1959 stated that it contained little of immediate practical value to sugar-cane growers. This is probably equally true of the 1960 Report, but growers of many other crops will find something of practical value, and even some sugar-cane growers may find something of interest.