ROTHAMSTED RESEARCH

Report for 1964

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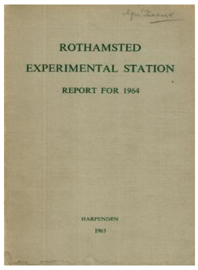

General Report

F. C. Bawden

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GENERAL REPORT

F. C. BAWDEN

It is melancholy to have to report four deaths, three of staff members and one of a member of the Lawes Agricultural Trust Committee.

H. Greene died suddenly in Lagos while on a tour of West Africa. His strenuous travels would have taxed the strength of a much more robust person, but it was typical of Greene that he undertook them unhesitatingly. Much recent work on tropical soils, especially in Africa, stems directly from his initiative and owes much to the encouragement and advice he gave unstintingly to those working in remote places. He is greatly missed, both at Rothamsted and in many places overseas, not only for his unique knowledge of tropical soils, but equally for his wise counsel on other matters and his invariable courtesy and geniality.

E. W. Buxton's death at the tragically young age of 38 robbed mycology of an outstanding exponent, for he was as excellent as a teacher as he was experimenter, and his colleagues of the pleasure and stimulation that come from working with such a lively and engaging personality. His great originality and industry had early gained him an international reputation in plant pathology and the genetics of fungi, but much as he had already done to enrich these subjects, he had the promise of still larger contributions to come.

C. F. Berry, like Buxton, bore a distressing illness with remarkable fortitude, and uncomplainingly went about his maintenance duties long after most people would have given up. Conscientious, reliable, loyal, all such adjectives apply to him, but there is none that adequately reflects our gratitude for such service.

Professor D. D. Woods, who succeeded Sir Alexander Fleming on the Trust Committee in 1955, was keenly interested in all our affairs, and we have benefited much from his advice. We are deeply indebted to him for devoting time to us that he could ill spare from his busy life.

The Lawes Agricultural Trust Committee. The Earl of Radnor retired from the Chairmanship of the Trust Committee, a position he had filled with distinction since 1938. It seems almost like the end of an epoch, for there are few members of staff who have served under any other Chairman, and the period has seen an immense increase in our scope of work, number of staff and physical facilities. We were fortunate indeed during such a period to have the benefit of his support and wise guidance. At a luncheon party during the June meeting of the Committee, we presented Lord Radnor with an album recording a few of the notable events during his chairmanship. Lord Radnor remains a Trustee. Sir Richard Verdin was elected to succeed him as Chairman of the Committee. The Royal Agricultural Society of England appointed Lord De Ramsey to the vacancy caused by Lord Radnor's retirement. The Royal Society of London appointed Professor W. T. J. Morgan to the vacancy caused by the death of Professor Woods.

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Awards. V. Stansfield was honoured by being appointed a Member of the Order of the British Empire in the Birthday Honours List. F. C. Bawden was awarded the degree of Doctor of Science (*honoris causa*) by the University of Hull.

Staff changes. V. Stansfield retired on 30 September after being the Station photographer for 40 years. There must be few members of the scientific staff during that period whose publications and talks have not reflected his great skill or who have not benefited from the shrewd comments of this outspoken Yorkshireman. F. D. Cowland was appointed to succeed him as Chief Photographer. F. J. Seabrook, who received the British Empire Medal in 1961, also retired on 30 September after giving the Chemistry Department 53 years of exceptional service.

Congresses and visits. There were five International Congresses on subjects that closely concern us, Soils, Biochemistry, Botany, Entomology and Photobiology, and the last three were held in the United Kingdom, so inevitably we had more visitors from overseas than for many years. The largest single party was on 11 July, when we welcomed 150 delegates to the Entomological Congress. Unexpectedly, even the Olympic Games added to our visitors, and provided us with a unique event on 19 October when we received a party of 80 students and staff from Tokyo University of Agriculture. The visit on 15 June by Paramount Chiefs from Sierra Leone was another unique and pleasant occasion.

The Soils Congress at Bucharest was the main occasion for members of staff travelling overseas, but far from the only one. It is impossible to meet all the requests we get for secondments, for advisory visits or for lecturing, but the departmental reports show that we did meet many. In addition to the visits recorded there, F. C. Bawden attended a meeting in Trinidad in January of the Advisory Technical Committee for the Regional Research Centre, University of the West Indies. He was appointed Chairman of the Agricultural Research Council of Central Africa by the British Agricultural Research Council, and attended a meeting of the Council in March at Blantyre, Malawi. At the invitation of the Conjoint Chemical Council of Ireland, he lectured at the University Colleges of Dublin, Cork and Galway in May.

The Saxmundham Experiments. In April we took over the responsibility for the crop-rotation experiments still remaining from those begun at Saxmundham in 1899 by the East Suffolk County Council. Although the soil there has a similar mechanical analysis to the clay loams at Rothamsted, it is in fact very different, much more difficult to work and drain, and crops respond very differently to phosphorus and potassium. The exact manuring of the different plots is known since the start of the experiment, and as with the classical experiments at Rothamsted and Woburn, the treatments will be modified to measure the effects of past manuring on soil properties, especially the changes in nutrients useful to crops, and to make the results more relevant to modern farming practices. In continuation of this policy at Rothamsted, we report some changes to the Park Grass

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Experiment; these are planned to give more information about the manuring of pasture and to provide soils with a more complete range of pH values, and they should add to, rather than detract from, the unique demonstration Park Grass provides of the effects of manuring on the composition of herbage.

Computation. The Orion computer passed its acceptance test in March and for four months gave satisfaction, but then entered a troublesome period, from which it did not emerge until the end of the year. Still further improvement will be required for it to handle the rapidly increasing requests for computation (a quarter more variate analyses than in 1963) in the analysis of experiments and surveys, much of which was done this year on the old computers. These machines will soon be dispensed with, but their continued use has greatly eased the transition to the Orion, for it has allowed time to develop satisfactory programmes for the Orion without getting any backlog of work. Several general and specific programmes were developed, and though this was greatly aided by the Extended Mercury Autocode made available to us by International Computers and Tabulators Limited, it still occupied much time. The use of this autocode has also enabled statisticians at other institutes to do their own programming and prepare tapes to use the computer directly.

Irrigation. An irrigation system to apply water to most of the fields on the Rothamsted farm was installed during the spring, but unfortunately we did not reap the benefit that we should have in such a dry summer and autumn because many unions in the underground piping proved faulty and it was rarely possible to apply water for any length of time without one bursting. All the underground pipes have now been relaid. An experiment gave some indication of what we lost; although less water could be applied than was intended, it increased yields of potatoes by up to 4 tons/acre and of grass by 10 cwt/acre dry matter. Watering potatoes after the time when tubers started to grow also had the additional benefit of lessening the severity of scab. In the Woburn irrigation experiment, watering sugar beet increased the yield of sugar by 1 ton/acre, and of clover by 16 cwt of dry matter; watering barley did not affect yield, for rain in the first half of the year was adequate for this crop; watering lucerne increased the yield by only 7 cwt dry matter/acre, and the value of this crop in drought was shown by the yield of 76 cwt dry matter/acre from the unwatered plots.

The crops in 1964. The requirements of different crops growing simultaneously often differ, so the weather in no year can be ideal for all crops, but in 1964 it favoured arable agriculture much more than it usually does, and our large programme of field experiments was completed without too much difficulty. November 1963 was wet and interfered with some work, but the next three months were all drier than usual, so that spring cultivations and sowing started exceptionally early. This was of great benefit because March and April were wet and field work could proceed only intermittently, so not all crops were in the ground until the weather improved in May. The first three weeks of June gave us more than 4 in. of rain, and harmed some hay, but the next six months were all much drier

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than usual and in total produced only 7 in. of rain, 9 fewer than the average. Most of the hay and all the cereals and beans were harvested rapidly and in excellent conditions, but inevitably the grass fields became brown and bare.

The ground was so dry and hard in the autumn that harvesting potatoes and sugar beet was difficult (at Broom's Barn the irrigation system was used to soften the ground and aid the lifting of beet); also, the potatoes were much bruised, as they carried little soil to cushion them. Ploughing had to be delayed until rain softened the ground, but then proceeded without interruption, so that by the end of the year all necessary autumn cultivations were done and all winter wheat and beans were in the ground, the first time for many years we have been in this happy position.

Yields were good, those of barley exceptionally so. Indeed, on the Rothamsted farm they averaged as much as wheat, which is very unusual. This may reflect the fact that powdery mildew was extremely prevalent on the wheat and susceptible varieties of barley, but we fortunately had changed almost completely over to resistant varieties of barley. Our largest yields were: winter wheat 58·5 cwt/acre; spring wheat 44; barley 47. Yields of barley and wheat were as great with the seed and fertiliser broadcast as with combine-drilling. The spring beans also did well, remained almost free from aphids and averaged a yield of 33 cwt/acre. Potatoes grew rapidly in June and July, but afterwards were affected by drought and put on little weight after the middle of August. Nevertheless, King Edward averaged 10 and Majestic 12 tons/acre. At Woburn and Broom's Barn, too, most crops yielded well, though barley at Woburn suffered from take-all. Sugar beet was attacked by both downy mildew and powdery mildew, and unwatered crops also wilted severely, but yellows was less prevalent than for many years, and yield was not increased by spraying against it. Yields ranged from 12 to 20 tons/acre and sugar content from 17 to 20%, averaging at least 1% more than usual. Aphids were generally few and, like sugar-beet yellows, other aphid-transmitted viruses also spread little, although at Woburn carrots were infested and motley dwarf spread in unsprayed crops: spraying increased the yield there from 14 to 19 tons/acre.

The remarkable contrast between the first and second halves of the year is vividly illustrated by the fact that although we recorded potato blight at Rothamsted a month earlier than ever before, so far from this leading to a serious epidemic, the disease never again got the opportunity to spread and did less damage than for many years. This was not so everywhere; in an experiment in the fens, where blight also occurred unusually early, protective spraying with fungicide increased the yield of tubers from 8·5 to 14·2 tons/acre, by far the largest increase we have ever measured. Conditions did not allow us to test our wax formulations against blight, but they did provide an opportunity to test the idea that spraying is harmful in dry seasons; none of the materials used significantly affected yield. An experiment in Devon, where blight spread during August, showed that three applications of our wax formulation of oxychloride was as effective as four of the best other material used.

In 1963 wheat-bulb fly was so devastating on some of the plots after

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fallow on Broadbalk that the crop failed and was ploughed in. There was the possibility of this happening again in 1964, when the infestation was even greater than in 1963. In the event, though, damage was much less, showing the importance of the stage of the crop when the pest is active. Although rather more plants became infested than in 1963, many fewer were killed, for whereas after the extreme winter of 1962–3 the wheat was still in the single-shoot stage during late April, at the same time in 1964 it was tillering. The amount of damage done by the pest on different plots differs considerably, but the differences do not reflect differences in the size of the initial infestation; rather they depend on fertility differences, which determine whether or not attacked plants are vigorous enough to compensate for damage and replace killed shoots. This well illustrates the difficulty of predicting likely losses from knowledge of pest populations and why we are paying increasing attention to other factors. Obviously, pests will not do significant damage unless they exceed a minimum number, and in similar circumstances the damage they do will be related to their numbers, but numbers are not all important, and infestations that are damaging in some conditions may not be in others. We report attempts to improve the control of wheat-bulb fly by insecticides, but this, like seeking substitutes for the chlorinated hydrocarbons to use against wireworms, is not proving easy.

Resistance to insecticides. Wheat-bulb fly and wireworms are only two out of many pests for which we seek improved methods of chemical control, and our work with pesticides extends far beyond simply measuring their effects on pests and crop yields. We are concerned with their effects on other organisms, not simply on insects beneficial to crops, such as honey-bees or predators of pests, but also on the general population of soil animals, and we study the persistence in the soil both of the chemicals applied and the effects they produce. Soil animals are affected much less by organophosphorus compounds than by chlorinated hydrocarbons, and their effects, like those of triazine herbicides, are only transient. Different chlorinated hydrocarbons differ in their stability in soil, but with most of them at least half of what is applied still remains after one year, so that they will accumulate when applied annually is evident. The most stable is DDT, of which half the original amount applied still remained after three years. However, the considerable changes in the proportions of different animals initially produced by adding 6 lb DDT/acre have greatly diminished after three years.

That the proportions of different species changed reflects the fact that individual species differ in their susceptibility to different insecticides. Unfortunately the reasons for this are little known, because the mechanisms by which most insecticides kill are still obscure, and there is no way of predicting whether one that is active against one species will also be active against another. This can be determined only by testing, and the discovery of chemicals acting specifically against pests will remain largely a matter of trial and error until more is known about the factors determining susceptibility. Not only do different species differ in their susceptibility to a given insecticide but so often do individuals of one

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species, and it is common for a species that has been exposed over a period to an insecticide to develop strains that resist the insecticide, that is, strains that are killed only by larger amounts of the insecticide than previously.

It is to seek further information about the mechanism of insecticidal action that we compare the behaviour of resistant and susceptible strains of houseflies, and our results make it clear that there is not going to be any simple answer. Evidence from several different lines of work shows that the permeability of the cuticle, especially its deeper layers, to an organophosphorus compound (diazinon) plays an important part and that the compound moves much faster into susceptible than into resistant flies. However, this is far from the whole story, for diazinon also breaks down much faster in the resistant flies. Organophosphorus compounds are generally thought to kill because they irreversibly inhibit the cholinesterase of the central nervous system; whether more diazinon is needed to do this in resistant than in susceptible flies is uncertain, but it seems that inhibition may not always be irreversible, for some flies that were paralysed by diazinon did not die but recovered.

Strains that resist one insecticide may also resist others, but again prediction is impossible and which ones it will resist must be determined by trial and error. A strain of housefly selected for resistance by exposure to organophosphorus compounds had very different degrees of resistance to different compounds, even to some compounds that differ only slightly in composition, but it was also very resistant to chlorinated hydrocarbons, especially DDT. Indeed, its resistance to this compound was considerably greater than that of a strain selected for resistance by exposure to DDT; also, it had an additional cause of resistance, for it still strongly resisted the action of DDT when this was given along with a substance that destroys the resistance of the other strain. Hence, although a concept can be advanced of resistance depending on the rate poisons penetrate the insect's cuticle and are degraded to harmless compounds after they have penetrated, this generality provides no explanation for the specific mechanisms that allow insects to resist some but not other insecticides.

Collections of aphids made in East Anglia were tested for their susceptibility to organophosphorus insecticides. All those of the black bean aphid were uniformly susceptible, but different collections of the peach-potato aphid differed greatly. The least and the most susceptible both came from districts where organophosphorus compounds have been much used to control aphids on sugar beet.

The health of seed tubers. It is rather ironical that the phrase health of potato seed tubers is now almost accepted as referring to infection by viruses and that this, together with purity to variety, dominates the seed certification scheme, for the scheme was started because of a fungus disease (wart). Our survey of the health of potato seed tubers, made in conjunction with the Potato Marketing Board, was concerned with fungus diseases and again showed the desirability of including tuber inspection as a part of the scheme, even though skin spot was less prevalent (30% of tubers from 200 stocks infected) than in 1963 (78% infected). Black scurf was

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more common (22 compared with 8%) and there were also considerable numbers of tubers with dry rot, gangrene, common scab, powdery scab and blight.

Severely affected tubers can, of course, be rejected at planting time, but this obvious loss to the ware grower may not be the only one, for the planting of infected tubers that grow and produce plants gives smaller crops than would be got from uninfected seed tubers. For example, most growers fear skin spot because the fungus can kill eyes and so lead to a gappy or thin crop. We again showed that this effect can be prevented by boxing infected seed tuber sbefore January, but other tests showed that this is not the only effect and that the fungus restricts yield in crops with a full stand of plants. By growing rooted stem cuttings, tubers were produced free from the skin spot fungus, and planting these clean tubers gave a crop that yielded 25% more than the crop from sister tubers that were inoculated with the fungus. Both lots of seed tubers produced a full stand of plants with vigorous haulms, but the underground parts of those from the inoculated tubers were browned by the fungus, as they often are in crops planted with commercial lots of seed. Similarly, plots planted with seed tubers free from black scurf outyielded those planted with infected tubers. The amount of fungus on the progeny tubers was correlated with the amount on the seed tubers, and it seems that, as with viruses, the planting of infected seed perpetuates the troubles. Now that seed tubers have been largely freed from aphid-borne viruses, some attention should be given to other tuber-borne complaints. It is easy to get tubers free from these fungi by rooting stem cuttings, and tests are now needed to see whether the small batches produced in this way can be kept free while being propagated to commercial amounts. There will be little incentive to do this, however, unless the effect these fungi have on yield is appreciated, and seed certification schemes recognise their existence.

Problems of light-land farming. On the heavy land at Rothamsted cultivations are often more difficult than on the light land at Woburn and the lifting of potatoes and sugar beet far more so, but it is much more difficult to get consistently good yields at Woburn, even when fertilisers are given generously. A smaller capacity to hold water is one reason, but more important seems to be that many soil-borne pests and diseases are favoured by the lighter land. Crop rotations that at Rothamsted continue to give good yields of cereals, potatoes, sugar beet or lucerne can lead to serious losses at Woburn from eelworms and soil-borne fungi. We have previously reported at Woburn a condition of cereals we call "scorch", most serious in dry springs and with crops given abundant nitrogen, and which is associated with the brown foot rot fungus. An experiment with spring wheat, designed to indicate the relative importance of water, nitrogen and fungus, failed in its initial purpose, for all plots were embarrassingly free from "scorch", presumably because the spring was wet and brown foot rot was not prevalent, but it nevertheless gave striking results, with grain yields from different plots differing by as much as a factor of four. Plots given 0·6 cwt fertiliser nitrogen/acre yielded only 9 cwt/acre; doubling the nitrogen and giving extra water increased the yield to only 18 cwt, whereas

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plots partially sterilised with formalin yielded 26 cwt when given the smaller amount of nitrogen and 37 cwt when given the larger amount and extra water. The main effects of formalin were to diminish attacks by cereal root eelworm and the take-all fungus, but there may have been others. The point to be made is that this land had not carried cereals more often than is now common practice in eastern England and that a spring-sown cereal grown in a similar sequence of crops at Rothamsted would not have been crippled by soil-borne pests and diseases. The average yield of winter wheat at Woburn in 1964 was 35 cwt/acre, which is more than usual, but different fields yielded very differently, and on those least infested with soil-borne pests and diseases yields exceeded 50 cwt/acre, which is what we expect at Rothamsted. The traditional association of wheat growing with heavy land is understandable, but light land can give equally large yields provided the wheat is adequately fed and protected from soil-borne pests and diseases.

Sugar beet also has its troubles on light land, and the condition generally known as "Docking disorder" was widespread this year. However, many crops that were so severely affected in May and June that it seemed they were likely to fail, later recovered and yielded moderately well. The condition may well have several causes, with the stunting of the top growth reflecting damage to the roots by very different agents. Soil-borne pathogens seem not always to be responsible, for steaming some soils has not improved the growth of beet; these soils, which have a very poor structure, contain much sand, and their physical properties seem such that conditions in the soil sometimes directly harm the roots, perhaps by asphyxiation. However, more often pathogens seem responsible, for beet grows well after some soils are partially sterilised. In 1963 beet in several crops with "Docking disorder" were found to be infected with the soil-borne viruses tobacco rattle and tomato blackring, both of which are transmitted by eelworms. The role of the viruses, however, was uncertain, for many stunted plants were not infected. Further work in 1964 suggests that the viruses are probably incidental, serving to indicate that the soil contains the free-living eelworms that transmit them, and that the main damage is done by the eelworms eating the young roots. These eelworms differ from the beet eelworm, long known as an important pest, for they do not enter the roots or form cysts, but live free in the soil and can feed on the roots of many different species of plants. The restrictions on the frequency with which beet can be grown on the same land, imposed to prevent beet eelworm increasing, are unlikely to affect their prevalence. If these are a major cause of "Docking disorder" it is easy to explain the difference in its incidence in different years. Whether crops are damaged by a given population will depend on the size and vigour of the root systems at the time conditions in the soil allow the eelworms to move to the roots and browse on them. It seems likely, however, that there are still other causes, for not all stunted beet was on land where free-living nematodes were abundant, and the way affected plants are distributed in some crops differs from the pattern typical of eelworm infestations. Some patterns resemble "fairy rings", but if soil-borne fungi are concerned they have yet to be identified.

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Soils and fertilisers. Fertile soils are traditionally thought of as those rich in organic matter, and the phrase good farming carries with it the connotation of maintaining soil organic matter, either by using dung or by such practices as ley farming or ploughing in green crops. Certainly arable crops often yield more where they are given organic manures or where they are interspersed with leys than where they are not, but this fact is far from demonstrating that such practices are essential or that they are economically the most rewarding. When fertilisers were expensive relative to the value of arable crops and labour was plentiful to handle and apply dung, the traditional practices had much to recommend them, but conditions now are otherwise.

We have for long made experiments measuring relative responses of crops to organic manures and mineral fertilisers, and the effects of the two on soil fertility. Dung has often given seemingly specific responses, but on further examination these have usually proved explicable because it contained more of some nutrient than was applied in the mineral fertilisers, and by altering the dressing of minerals or the way in which they are applied, yields have usually been increased to equal those got with dung. Another such response at Woburn, the better growth of early carrots with dung, was abolished this year by giving 3 cwt P_2O_5/acre, which produced better carrots than did dung. Some of the light land at Woburn contains very little organic matter, and its structure is extremely poor, but most crops will do well on it provided they are given enough mineral nutrients and are not harmed by soil-borne pests. However, a few crops, and globe beet especially, germinate more evenly, and grow better as seedlings, when the physical structure is improved by organic matter.

Many of our experiments provide evidence that soil fertility can be maintained by mineral fertilisers only. Broadbalk gives the longest experience, where for more than 120 years plots 7 and 8 have received only ammonium sulphate and other minerals, yet they yield as much or more wheat than plot 2, which annually has had 14 tons/acre of dung. Our ley–arable experiments are relative youngsters, only 16 years old, but they provide information about more crops and over a wider range of treatments. The one in Highfield is on land ploughed from old pasture at the start of the experiment, the one in Fosters field is on land that had long carried arable crops. Each experiment has the same six-course rotation, all arable crops on some plots, whereas on others three arable crops follow three years of ley, either lucerne or grass. As the experiment has continued and the manuring has been adjusted in the light of experience gained, the yields of the test arable crops have increased greatly, with wheat often exceeding 2·5 tons, barley 2 tons and potatoes 14 tons/acre. The best yields are remarkably similar in both fields, despite great differences between the amounts of organic matter in the soils, and are as great with the continuously arable cropping as after three years of a ley. On Highfield the organic matter is diminishing with all the rotations, no faster with the sequence of all arable crops than with the rotation containing lucerne, but slightly faster than with the grass leys. The organic matter in the soil on Fosters remains almost constant, but is increasing slightly with the grass leys, though not with the lucerne. In contrast to the effects of the grass

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and lucerne leys on the soil organic matter, wheat consistently yields more after lucerne than after grass. In the all-arable sequence the yield of wheat can be made to equal that after lucerne by giving it enough nitrogen, but we have not yet achieved this after grass. The reasons for yields being smaller after grass are obscure, but it is evident that the traditional practice of resting land from arable cropping by putting it down to a grass ley is not only unnecessary to maintain fertility but can also be less rewarding than other practices.

Many of our other experiments also show that soil fertility can not only be maintained but enhanced by mineral fertilisers, and that these leave residues that are no less beneficial than those from organic manures. For unknown reasons, residues from both kinds sometimes increase crop yields beyond those readily obtained by giving fresh fertiliser. Last year we stressed the need when using fertilisers to consider past manuring and cropping. Then we had in mind mostly effects of organic nitrogen and of inorganic phosphorus and potassium, because little inorganic nitrogen usually remains to feed a second crop. However, when deciding how much nitrogen to give, it can also be very rewarding to consider what was the previous crop and how much that got. For example, although nitrogen given to wheat seems to have no residual value for the next crop on that land, nitrogen given to potatoes can have great residual value for a succeeding wheat crop. Indeed, after potatoes that were given a large dressing, but no larger than was economically justified, wheat given no further fertiliser yielded as much as did wheat that was itself given one-third the amount given to the potatoes. To save 0·5 cwt N fertiliser/acre is well worth a little thought.

The intrinsic fertility of a soil depends on the nature of the parent material from which it was formed and the ways the parent material has been altered by weather and by organisms. The Soil Survey, which mapped a further 1,100 square miles in England and Wales during 1964, uses these features to classify soils. Although the maps are already very valuable aids in reaching decisions about land use, not only suitability for specific crops but for many other purposes, their agricultural value would be much enhanced could the soil type be used as a guide to the fertiliser requirements of crops. We have therefore started trials to measure the response of crops to fertilisers on different soil series, and the first results suggest there may be considerable differences.

The items selected for comment in this section are only a small minority of the many dealing with soils and fertilisers that are described in the pages that follow. The departmental reports and articles also contain much of scientific interest and practical importance on many other subjects that there is no space even to mention in this general report.

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