ROTHAMSTED RESEARCH

Report for 1954

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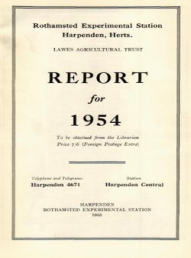

Introduction

Sir William G. Ogg

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INTRODUCTION

BY THE DIRECTOR

Rothamsted suffered a great loss in the death of Dr. E. M. Crowther on 17 March 1954 at the early age of fifty-six. He joined the staff in 1917, and ten years later, when he was only thirty, was appointed Head of the Chemistry Department, a position he occupied until his death. In 1950 he became one of the two Deputy Directors of the Station. Accounts of Dr. Crowther's career and of his outstanding contributions to agricultural science, and particularly soil science, have appeared elsewhere; a list of his published papers is included in this report. His whole professional life was devoted to Rothamsted, and his influence on the policy and research work of the Station was profound. He is greatly missed for his scientific leadership and equally as a friend for whom we all had the greatest affection.

Professor A. C. Chibnall, a member of the Lawes Agricultural Trust Committee since 1943, and Sir E. B. Bailey, a member since 1944, both representing the Royal Society, retired from the Committee in November 1954, and were succeeded by Professor A. Robertson and Professor V. B. Wigglesworth. In succession to Dr. E. M. Crowther, Dr. R. K. Schofield was appointed to the Headship of the Chemistry Department, and Dr. H. L. Penman succeeded Dr. R. K. Schofield as Head of the Physics Department from October, 1954. Dr. P. H. Gregory, who joined the Plant Pathology Department as Mycologist in 1948, left at the end of January 1954 to become Professor of Botany at the Imperial College of Science and Technology, London. At the request of the Colonial Office, Dr. A. Muir visited Nigeria to advise on the Nigerian Soil Survey. He attended the 2nd Inter-African Soils Conference and the 5th International Congress of Soil Science in the Belgian Congo, and visited Northern Rhodesia, Nyasaland and the East African Colonial Territories. Dr. H. Greene led the United Kingdom delegation at the Inter-African Soils Conference and attended the 5th International Congress of Soil Science in Leopoldville. He also made a tour of Colonial Territories in West, Central and East Africa, and visited Aden and British Somaliland. Dr. C. B. Williams spent two months at the West African Cacao Research Institute at Tafo, Gold Coast, to advise on insect pests of cocoa; Dr. F. Raw has been seconded to the Institute to investigate the damage done to cocoa by capsids, and Miss Margaret Holden to work on problems connected with swollen shoot disease of cocoa. Dr. A. W. Taylor has been awarded a post-doctorate fellowship at the University of Wisconsin, Madison, and Dr. D. M. C. MacEwan has been given two years' leave of absence to work in the Faculty of Sciences in the University of Granada. To get a wider knowledge of the biology of forest soils, Dr. P. W. Murphy is spending a year with Professor Kühnelt in the Zoology Department of the University of Vienna. Mr. C. A. H. Hodge has been seconded from the Soil Survey to the Government of Aden for several months, and Mr. L. F.

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Curtis to Hunting Aerosurveys for six months' work in Iraq. Mr. G. E. Hodnett spent four weeks visiting agricultural and statistical departments in the West Indies. Other members who spent shorter periods abroad to learn special techniques were Dr. J. M. Bremner, who worked for three months with Professor W. Flaig, Director of the Institute of Soil Biochemistry, Braunschweig-Völkenrode, and Dr. B. Kassanis, who studied tissue culture techniques with Dr. Morel at the Station de Physiologie Végétal, Versailles.

Sir William Ogg was one of a party of five agriculturists from the United Kingdom who attended on behalf of the Ministry of Agriculture the All-Union Agricultural Exhibition of the U.S.S.R. in Moscow in August, at the invitation of the Soviet Ministry of Agriculture. He also paid a brief visit to the Dokuchaev Soil Institute.

Representatives from Rothamsted attended the International Congress of Geodesy in Rome, the 15th International Beekeeping Congress and International Conference of Bee Research workers in Copenhagen, the International Union of Crystallography and Supplementary Meeting on Clay Minerals in Paris, the International Botanical Congress in Paris, the International Photobiological Conference in Amsterdam, the Conference of the International Union for the Protection of Nature in Copenhagen, meetings of the International Institute of Sugar Beet Research in Belgium and Eire, and the Virus Yellows Colloquium at Bergen-op-Zoom.

Mr. F. C. Bawden accepted the invitation of the Indian Science Congress Association to attend the Science Congress at Hyderabad in January, and afterwards visited Indian Universities and agricultural research stations. Dr. H. G. Thornton a member of the UNESCO Advisory Committee on Arid Zone Research, visited India in October to attend a meeting of the Committee in New Delhi, followed by a Symposium on Solar Energy and Wind Power organized by UNESCO and the Indian Government; Mr. N. W. Pirie also attended the Symposium. Dr. D. A. Osmond attended a meeting at Ghent of a sub-group set up under F.A.O. to study soil classification and survey in Europe. Dr. G. W. Cooke was invited to spend six weeks at the Headquarters of F.A.O. in Rome, to prepare their "Annual Review of world production and consumption of fertilizers"; he also attended the General Assembly of the International Centre of Chemical Fertilizers in Zurich.

Dr. C. B. Williams was elected a Fellow of the Royal Society. Sir William Ogg was elected President of the Society of Chemical Industry for a second year from July 1954.

Visitors

Over three thousand visitors from many countries came to Rothamsted in 1954. H.R.H. the Duke of Edinburgh paid an informal visit on 20 July, spending the morning on the experimental farm and the afternoon in the laboratories. Other visitors included Vice-Admiral Sir Peveril William-Powlett, the Governor, and Mr. Garfield Todd, the Prime Minister, of Southern Rhodesia; The Hon. R. C. Wilson, C.M.G., a member of the Legislative Council of New South Wales; Sir Charles Jeffries, K.C.M.G., O.B.E., Deputy Under-Secretary-of-State for the Colonies; Sir Alan Hitchman, K.C.B.,

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Permanent Secretary to the Ministry of Agriculture and Fisheries; Mr. Milan Ivanovic, Yugoslav State Counsellor of Agriculture; a party of senior Danish officials, including the Permanent Secretary to the Ministry of Agriculture; and many scientists from overseas. Amongst parties visiting Rothamsted were members of the Parliamentary and Scientific Committee, the Comparative Medicine Section of the Royal Society of Medicine, the 5th Commonwealth Mycological Conference, a French Technical Mission, the 6th Commonwealth Entomological Conference, and the Jubilee Conference of the Association of Applied Biologists.

Buildings

During the year the new temporary building for the Statistics Department has been completed. This houses the electronic computer and provides a much-needed conference room and additional accommodation for staff and temporary workers. The buildings for fertilizer work and for experiments on the production of leaf protein have also been in use since the early summer. The new Plant Pathology building is nearing completion.

The Work of the Station

Several lines of fundamental research in the **Physics** Department are proving useful or showing promise. During the year, H.M. Stationery Office has published for the Ministry of Agriculture a Technical Bulletin on the calculation of irrigation need in England and Wales, which, with valuable help from others, is mainly a joint effort of the Physics Department and the Agricultural Branch of the Meteorological Office. This estimate of need is purely meteorological, but as agricultural interest quickens, more field experiments will show how far the meteorological data supply a farming need. An experiment at Woburn has already shown that irrigation of grass and early potatoes is very much worth while. Intensification of production has been accompanied by an increase in diseases and pests, and in recent years attention has been given to the microenvironment of the growing crop; there has been a steady development of techniques for measuring the " weather " experienced by plant pathogens and insect pests. This involves collaborative work with the biologist, and recent work on the potato crop has given a broad picture of the conditions that might affect the activity of aphid vectors for virus diseases, and those that control infection and spread of potato blight. In parallel with these studies of the aerial environment of the plant, progress has been made on the soil environment. It is always assumed that good soil structure is an essential condition for successful farming, but research has been hindered by lack of a suitable way of expressing structure quantitatively; a new sodium saturation method for determining the stability of moist soil crumbs is proving useful, both in field and laboratory tests. There are indications that grass leys are more efficient than lucerne in improving soil structure, and it has been shown that certain synthetic soil conditioners are much more efficient in stabilization of acid soil than of soil containing free calcium carbonate, a result in accord with previous field experience. In addition to

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promising work on the mechanism of crumb formation, further progress has been made in the development of techniques for estimating the potash and phosphate status of soils.

In the **Chemistry** Department further work has been done on the agricultural value of phosphate fertilizers insoluble in water, and data have been obtained on solubility properties which will be of value in laboratory testing and in specifying the soil conditions which influence the effectiveness of the different calcium phosphates present in fertilizers. The radiotracer work on the uptake of phosphorus by plants has been continued and field experiments carried out for the third year to compare nitrophosphate with superphosphate plus equivalent nitrogen. Applied to cereals, the nitrophosphates tested gave poorer crops, but the difference was much less marked if they were drilled with the seed. Fertilizer placement experiments on horticultural crops showed marked benefits from placing fertilizers at the side of the seed for cabbage, lettuce, onions, maize, broad beans and runner beans, as regards both yield and earliness for market. Placing was twice as efficient as broadcasting for lettuce and cabbage; for beans, broadcast fertilizer was of little use. The increased returns may well be sufficient to justify the purchase of special placement drills for these high-value crops. In experiments with potatoes it was found that on the average 1 cwt. of nitrogen was sufficient for maximum yield, and there was no gain from splitting the nitrogen dressing and applying part at planting and part at " earthing-up ". It was often assumed that much of the benefit of placement was due to localizing the phosphate near to the seed and that for the more mobile nutrients, nitrogen and potash, broadcasting was satisfactory. The results of recent work, however, have modified this view, and it appears that for some crops, including potatoes, both nitrogen and potash are more efficient when placed close to the seed. Useful progress has been made in the improvement of laboratory techniques for determining ammonium and nitrate in soil and for studying the release of nitrogen and phosphorus in soil organic matter. In view of the fact that British farmers spend about £20 million annually on nitrogen fertilizers, these lines of work are highly important.

In several old forest nurseries " partial sterilization " of the soil by formalin and chlorpicrin has given consistently good results over a number of years, if applied during the winter before sowing. As soil treatments are difficult to apply during the winter months, summer and autumn applications were tested during a fallow period. The summer application of chlorpicrin and the autumn application of both materials gave promising results.

The **Pedology** Department continues to give much attention to processes of soil formation and to the minerals occurring in soils and soil clays. This work is very closely linked up with soil surveys, both in this country and in Colonial Territories. In a soil survey in Nyasaland, a study of the mineralogy has thrown light on the origin of the parent materials of the soils and confirmed the principles on which they have been classified. Additional work has been done on the gilgai soils of Kenya. Progress has been made with the study of clay minerals of soils and drifts, and particular attention has been given to the Clay-with-flints. The properties of clay minerals are being investigated, and new instruments for this

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purpose have been designed. In the spectrographic section, improved methods are being introduced which will enable the analyses to be done much more quickly and accurately. The study of the minor elements in the Lias clay and in numerous soils from Wales has been continued as part of the programme for determining their general distribution in the soils of Britain. Further studies have been made of the effects of materials washed out of leaves on soil constituents and on soil formation.

In the **Soil Microbiology** Department the possibility of using antagonistic micro-organisms to control root disease fungi in the soil is being explored. Various soil organisms, particularly certain actinomycetes, are a source of antibiotics used in medicine, but there has been very little evidence that antibiotics are actually produced in the soil and are active in it. Many actinomycetes are able to attack root disease fungi, but there has been doubt as to whether their antagonistic action in soil was due to competition for some essential nutrient or to antibiotic secretions. Evidence has now been obtained that it is an antibiotic action. It has been shown, first, that actinomycetes antagonistic to the root fungus *Helminthosporium* inhibit the germination of the spores of this fungus in soil and produce symptoms of toxic action on the germinating hyphae; secondly, that these symptoms are characteristic for the different actinomycete species tested and are exactly similar for each species to the symptoms shown in agar culture; thirdly, that the pure antibiotic " Actinomycin " produces the same symptoms on germinating spores in soil as are produced by *Streptomyces antibioticus*, which produces this antibiotic.

Further work has been done on the strains of clover nodule bacteria which either fail to produce nodules or produce nodules that are ineffective in fixing nitrogen. It has previously been found that on acid soils an effective strain often produced ineffective variant forms. Recent experiments have shown, however, that acidity is not the only factor. Different strains of bacteria differ greatly in their tendency to produce these ineffective variants, and attempts are being made to select genetically stable strains for use in seed inoculation. The investigation of the virus that destroys clover nodule bacteria is being continued, and a study made of the adaptability of free-living nitrogen-fixing bacteria to different levels of soil acidity and calcium content. Further work has been carried out on the decomposition of certain weed-killers and insecticides by soil micro-organisms, and in co-operation with the Bee Department attempts are being made to isolate and grow the organism which causes European Foul Brood.

In the **Botany** Department the work on plant nutrition has included studies of nutrient uptake and interaction between iron and other micronutrient elements. It has been shown that the disease known as " cloud " or " blotchy ripening ", which seriously affects the quality of tomato fruits, is not due, as had previously seemed possible, to manganese toxicity. The " cloud " symptoms were induced when plants at a late stage of growth were transferred to a more dilute culture solution. In further experiments on nutrient uptake from spraying foliage it was shown that absorption of phosphorus through the leaves of swede plants may reduce uptake through the roots by a corresponding amount. This happens, how-

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ever, only when the supply of phosphorus to the roots is high relative to other nutrients, and not when there is a balanced supply of nitrogen, phosphorus and potash. Weed studies have been continued, with special attention to wild oats. Experiments comparing the effects of different winter- or spring-sown cereals on the establishment and growth of wild oats and other weeds have emphasized the importance of crop competition in limiting weed infestation. Other lines of work in the department include studies of the physiological effects on plants of virus infection and of the physiological limitations of crop yield. A field experiment on kale showed that there is an optimal leaf area, per unit area of land, for dry matter production. When this is exceeded, in a heavy crop, the rate of dry matter production is then reduced, because the leaves interfere with each other and their average photosynthetic efficiency is decreased, presumably by mutual shading.

Most biological processes depend on the action of enzymes, and the **Biochemistry** Department continues to devote most attention to the detailed study of some representative enzyme systems. Work on the ribonucleases has been carried as far as it is intended to take it at present, and is now being published. The study of various oxidizing systems continues, both because they are widely distributed in nature and because a better understanding of them is likely to help in interpreting the effects of trace metal deficiencies. Although a knowledge of enzymic differences between bracken and crop plants will obviously not necessarily lead to a method for eradicating bracken, this knowledge will probably help. A comparative survey of the enzymes has therefore been begun.

All work on enzymes involves the study and purification of proteins, and highly-purified preparations of peroxidase and ribonuclease have been made. The properties of purified virus preparations have also been investigated. This work is done with very small quantities of material. At the other extreme, progress has been made in the extraction of protein from leaves in bulk. With a pulper and press designed for this purpose, fresh greenstuff can be processed at the rate of 1 ton per hour and one-third or more of the protein extracted. The best methods for making dry protein from this in a form suitable for feeding to non-ruminants, including man, are now being studied. Until this has been done it is not possible to judge whether this method of getting food from a crop is economic. It is, however, already clear that with the new continuous press it is possible to remove much of the water from grass, and this may lead to economies in commercial grass drying.

Two other lines of work deserve mention. The first is on the effect of variations in illumination on the concentration of organic acids in the leaf. This is being done in the hope that it may provide an explanation of the effect that such variations have on the susceptibility of the leaf to virus infection. The second is a study of the chemical nature of those components of fungal mycelia that are resistant to attack both by enzyme preparations and mixed soil organisms. Such material may be expected to accumulate as part of the soil organic matter.

In the **Plant Pathology** Department much new information was obtained about the conditions that favour infection and virus

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multiplication in leaves newly inoculated with viruses. Virus particles seem to be continually synthesized and broken down in infected cells, and the ratio of breakdown to synthesis is increased by increasing temperature. Many experiments were made with the insect-transmitted viruses that affect cruciferous crops; the incidence of the aphid-transmitted cauliflower mosaic was decreased by surrounding seedbeds with rows of barley; of two flea-beetle transmitted viruses found damaging field crops, one was related to turnip yellow mosaic virus, but the other seems distinct from any previously recognized and is provisionally called turnip crinkle virus. *Beta maritima* tolerated infection with strains of sugar beet yellows virus better than did *B. vulgaris*, but varieties of sugar beet also differed greatly in their response to infection; usually, but not always, the yield of roots was correlated with the severity of leaf symptoms. Normal-looking plants of many potato varieties were found to contain a virus serologically related to carnation latent virus; the virus in potatoes was not transmitted by aphids that transmit the one from carnation, and the two infect different kinds of plants.

In conjunction with the Insecticides Department experiments were done on the spraying of potato crops with persistent insecticides. This prevented the spread of leaf roll and decreased the spread of severe mosaic between plants within a crop, but did not prevent these diseases being introduced into healthy crops. The incidence of yellows in beet, both stecklings and the root crop, was decreased by spraying with systemic insecticides; although yellows was not prevalent early in the season, spraying considerably increased yields in some root crops.

Potato blight was exceptionally damaging at Rothamsted in 1954 because the crop grew slowly and only one-third of the potential yield of tubers was formed when the disease became prevalent; fungicidal sprays increased the yield by 2·4 tons/acre, whereas in 1953, when blight was prevalent at the same time, they gave an increase of only 0·5 tons. In experimental plots in which infected tubers were planted, blight first appeared on 28 May, and there were six "generations" or "spreads" of infection before the fungus became plentiful enough to cause general infection about the end of July. The wet summer made eyespot unusually prevalent in all the wheat experiments, and further evidence was obtained that the optimum seed rate depends on whether or not the land is infected with this and take-all fungus. On contaminated land a seed rate of 1½ bushels of the variety Squarehead's Master gave higher yields than 3 bushels, but not on clean land. The optimal seed rate, however, varied with the different wheat varieties. The effect of seed rate on lodging in spring-sown Proctor barley was tested at three levels of nitrogen; lodging was particularly severe with high seed rate and heavy nitrogen dressings. In this experiment, increasing the seed rate from 1 to 3 bushels and ammonium sulphate from 1½ to 3 cwt. increased the rate at which the crops lodged without increasing the yield of dressed grain. Further work on cereal mildews showed that their incidence was increased by late sowing and by nitrogenous fertilizers; the yield of Plumage Archer barley, a susceptible variety, was increased by amounts up to one-third by spraying with fungicides; spraying a resistant variety (Haisa II) gave no increase. In an investigation on pea diseases, a range of

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Fusaria was isolated, which together and separately cause three diseases. *F. oxysporum* causes wilt, *F. solani* root rot, and the two together " St. John's Disease ", which is less severe than the other two and previously recognized only in continental Europe. Cultures of *F. oxysporum* pathogenic to the seedlings of Sitka spruce were isolated from diseased plants in forest nurseries, and this may contribute to the difficulties in raising healthy plants in old nurseries.

Further work carried out with fungicides to control seedling diseases of sugar beet gave evidence of the benefits derived from soaking the seed in solutions of ethyl mercury phosphate. In the Docking district of Norfolk and certain other places with light, alkaline soils, sugar beet are often subject to what has been termed " Docking Disorder ". Two fungi, *Pythium* and *Rhizoctonia*, have been isolated from affected plants, but they seem to be insufficiently virulent to be the chief cause of the trouble. Work has been continued on *Botrytis cinerea*, which is the main cause of rots in stored sugar beet and in clamped fodder beet and mangolds.

The **Nematology** Department is giving much attention to the study of eelworm populations and conditions under which they build up. In an experiment on cereal root eelworm at Stoke-on-Tern (Salop), an estimate is being made of their annual rate of multiplication in soil cropped with cereals, both winter and spring sown, with and without fertilizers. At another centre, the eelworm population increased under barley and dropped under linseed and cocksfoot. Observations are also being made of eelworm numbers on some of the old experimental fields at Rothamsted. For instance, beet eelworm on Barnfield has been surveyed for the third time. In spite of the host crops (mangolds and sugar beet) being grown every year, the eelworm population has remained about the same since 1946, and broadly speaking the parasite is most prevalent on the plots where the manurial treatments give the highest yields. The cereal root eelworm has been found in low numbers on Broadbalk (continuous wheat) and Hoosfield (continuous barley), and detailed surveys are being undertaken.

Pot experiments have been carried out with tobacco, potatoes and brussels sprouts to ascertain the effect of different levels of eelworm population on the height and weight of the plants. In general, it was found that the stunting due to the parasite was proportional to the logarithm of the number of eelworms added. A very low infestation, however, gave slightly taller and heavier plants than the uninfested control pots. This effect can perhaps be ascribed to mild root pruning by the parasite.

Work has been continued on the relationship between eelworms and their host plants, including the resistance of varieties of cereals to eelworm attack. Further investigations have been made of the root diffusates which lead to hatching of cysts, and experiments started on the physiology of the potato root eelworm. Previous work had indicated that soil fumigation failed to kill eelworms near the surface, and it has been shown that this can be dealt with by drenching the surface with solubilized cresol immediately after injecting the fumigant. Such double treatments may be practicable in glasshouses.

In the **Insecticides** Department much attention is being given by the biochemists to the way in which the very poisonous organo-

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phosphorus insecticides act. It is generally assumed that they prevent certain necessary enzymes (the esterases) from functioning. This action on these enzymes in plants and insects is being studied, particularly the different effects they have on the enzymes of different species of insects. This is being done from the egg stage onwards, and the knowledge obtained may help in the search for organophosphorus compounds more poisonous to insects and less toxic to man. The biologists have spent most of their time on problems directly concerned with chemical control of pests of agricultural crops. A number of aspects of the control of black aphis (*Aphis fabae*) on field beans have been studied, and it has again been shown that considerable increases in yield can be obtained with a single early application of an insecticide. In the investigations on the control of wheat bulb fly (*Leptohylemyia coarctata*) progress has been made in laboratory rearing techniques which are essential for the study of its biology and control. Small-scale field experiments have indicated that effective control of larvae attacking the wheat plant may be obtained both with an insecticide in the soil and one applied later to the growing plant. These results require to be confirmed and amplified. Assistance has been given to the Home Grown Threshed Peas Joint Committee in a study of the chemical control of pea weevil (*Sitona lineatus*), and it has been shown that a systemic insecticide may be helpful though not a complete answer to the problem.

In the **Entomology** Department the work on insect migration and the effect of weather conditions on insects has been continued. Further work has been done on gall midges of economic importance, including a study of the biology of the Hessian fly and especially its host range. In view of the interest in clover seed production, investigations have been re-started on gall midges of clover, and it has been found that there is a widespread infestation of white clover by several species of midges, one of which is probably the well-known red clover seed midge. The midges of various grasses and lucerne are also being studied.

Much attention continues to be given to aphids, particularly to the way in which they spread and to their natural enemies. In the wheat bulb fly experiments, several new hosts have been found amongst the grasses, and the soil conditions favourable to egg laying are being studied. It has been suggested that soil organisms, especially earthworms, may play a considerable part during the rehabilitation of poor grassland, and, in co-operation with the Soil Survey, experiments have been laid down on two hill farms in Lancashire. In co-operation with the Nature Conservancy observations are being made on the effect of weed killers on insect populations.

The **Bee** Department continues to give attention to foraging behaviour, swarming and the social organization in the hive. It has been shown that foraging activities can be set going by the liberation in the hive atmosphere of a scent which the bees have already learned to associate with some source of food. This observation may help to explain some of the problems encountered when attempts have been made to direct bees to particular crops for purposes of pollination. There are also indications that flowers in which the nectar concentration is on the increase are particularly attractive to

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bees. Further work has been done on the nature and functions of "queen substance", which the bees of a colony seek by licking the body of their queen. It has been demonstrated biologically that this substance is present in the honey-stomachs of worker bees who have recently been in contact with a queen. It would appear that it controls not only the production of further queens but also the development of the ovaries of worker bees. By means of radio-active tracer technique additional information has been obtained on the extent to which the bees of a colony share the sugary liquids collected by the foraging members. Progress has been made with the work on bee diseases, including Nosema, Acarine disease and European Foul Brood. Various acaricides for the treatment of Acarine disease were tested, and one was found which killed all the life stages of the mite responsible for the disease without harming the bees. Work on queen introduction, bee-breeding, and the biology and behaviour of bumble bees has been continued.

In the **Statistics** Department much time has been devoted to investigating the possibilities of the recently installed electronic computer and adapting it to our needs. It has proved reasonably reliable, and has already done some useful work. It is often thought that the main feature of these machines is their speed, but equally important is their ability to perform long and complicated trains of operations without the intervention of the human operator. The introduction of electronic methods of computation will make available for regular use statistical methods which at present are scarcely used because of the heavy numerical work involved, and it will also facilitate and speed up many of the routine analyses which are at present done on desk machines. Progress has been made on various agricultural surveys. The Survey of hill and livestock rearing farms, which has just been completed, provides information on the returns being obtained from public and private expenditure, and will indicate what scope there is for further expenditure on upland farms. The Survey of fertilizer practice has been extended to twelve more districts, and a further Survey of rabbit damage has been carried out. Collaboration on the Survey of diseases of dairy cattle has been continued and assistance provided in various other livestock surveys. A good deal of work has been done on the re-organization of the long-term and classical experiments at Rothamsted and Woburn, and there has been the usual volume of routine work on the design and analysis of field and laboratory experiments for Rothamsted and other research stations and for the National Agricultural Advisory Service. Work for the Colonial Office has been continued, and a training course in sampling theory and practice, mainly for officers in the Colonial Service, which was organized jointly with the Division of Research Techniques of the London School of Economics, was held at Rothamsted.

The extensive programme of **Field Experiments** at Rothamsted and Woburn was carried out successfully in spite of very unfavourable weather conditions, and some 2,700 plots and over 500 micro-plots were handled by the experimental staff. A matter of great importance for the classical experiments was the mapping of the soils for calcium carbonate and pH. As a result of the situation revealed by this survey, liming schemes for Broadbalk, Hoosfield, Agdell and the Exhaustion Land were approved by the Lawes

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Agricultural Trust Committee and have now been carried out. The acid areas had arisen from two causes: first, irregularity in the original application of chalk and, secondly, losses of calcium carbonate due to repeated dressings of ammonium sulphate and, to a lesser extent, rape cake. The schemes are designed to correct the first of these by a single chalk dressing and the second by a compensating application of chalk with the above manures. The four-course rotation, testing residual effects of organic manures and phosphatic fertilizers, has now been completed, and the results obtained since the experiment was started in 1930 have been summarized. The first complete set of test crops on the ley–arable rotation experiment, started in 1949, has been harvested, and interesting differences are already emerging. Most of the annual and short-term experiments are discussed in the reports of the various departments.

At Woburn, the declining level of yield on the classical wheat and barley plots is probably due mainly to increasing soil acidity and weed competition, but there may be other factors. A liming programme has now been drawn up which should greatly increase the value of these experiments, and enable the effect of liming on weeds to be studied. The irrigation experiment, testing controlled watering of agricultural crops, encountered a wet summer, in which even the cocksfoot ley showed little or no benefit from irrigation. Watering, however, doubled the percentage of self-sown *Poa annua* in the ley. The poor summer enabled the behaviour of exotic crops under very unfavourable conditions to be studied. Early ripening varieties of maize from Wisconsin and Holland ripened a month later than usual after a poor start, and gave satisfactory yields, but the grain had to be artificially dried. Sweet lupins were sown late in order to reduce the proportion of inedible stalk, and even in this unfavourable year gave a useful yield of dry matter. Serradella clearly suffered from the cold season, but nevertheless yielded nearly 2 tons per acre of high protein feed, and promising results were obtained with a new German strain of Jerusalem artichokes. Laboratory work on the sulphur content of the classical barley soils has been completed, and indicates that the sulphur received from rain and other atmospheric sources is sufficient to maintain the sulphur content of the soil.

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