ROTHAMSTED RESEARCH

Rothamsted Report for 1951

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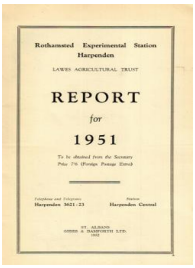

Plant Pathology Department

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PLANT PATHOLOGY DEPARTMENT

By F. C. Bawden

In October T. W. Tinsley was seconded for two years to the West African Cacao Research Institute ; F. M. Roberts' period of secondment to the Clove Research Scheme, Zanzibar, was extended until August 1953.

L. Broadbent and M. A. Watson attended the International Congress of Entomology at Amsterdam in August ; L. Broadbent also attended a conference on potato virus diseases at Wageningen and visited research centres in western Germany, at the invitation of workers there. R. Hull spent August and September in the United States and Canada visiting institutes at which diseases of sugar beet are studied. At the invitation of the Organizing Committee, F. C. Bawden attended the Second International Poliomyelitis Conference at Copenhagen in September. At the request of the Pyrethrum Board, P. H. Gregory visited Kenya in December to advise on the " bud disease " of pyrethrum.

P. H. Gregory was President of the British Mycological Society. T. W. Tinsley was awarded the Ph.D. degree of London University.

Viruses and Virus Diseases

Ultraviolet irradiation

Methods were developed for testing the goodness of fit to various hypotheses of infectivity tests with irradiated preparations of plant viruses, and, with few exceptions, the results agreed with inactivation being a first order reaction. Over a wide range of concentrations, the infectivity of partially inactivated and control preparations behaved similarly when diluted, and there was no evidence that plant viruses give the phenomenon of " multiplicity reactivation," a phenomenon described with bacteriophages of *Bacterium coli* with which particles that are non-infective singly cause infection when two or more enter the same cell. The only differences between dilution curves of irradiated and control preparations were at high virus concentrations, when, instead of the irradiated preparations causing more lesions than would be expected, they caused fewer, evidence that the inactivated particles not only failed to reinforce one another but interfered with the establishment of active ones.

The extent to which irradiation reduced infectivity of tomato bushy stunt and tobacco necrosis viruses depended on whether inoculated leaves were exposed to visible light after inoculation. Preparations that appeared to have their infectivity reduced to 1 per cent by irradiation when inoculated leaves were kept in the dark, had 4-10 times as much residual infectivity when inoculated leaves were exposed to daylight. Illumination of the irradiated virus preparations *in vitro* did not enhance their infectivity ; the effect is not a direct one of light on the virus particles but indirect through some light-sensitive system contained in the host cells. The phenomenon does not apply to tobacco mosaic virus, irradiated preparations of which show the same residual infectivity whether inoculated plants are illuminated or not.

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The damaging effect of ultraviolet to plants were also counteracted by visible light. For example, leaves of *Phaseolus vulgaris* irradiated for two minutes showed no macroscopic effects if they were subsequently kept in daylight, but the irradiated epidermis died when leaves were kept in darkness after irradiation (Bawden and Kleczkowski, 78).

Experiments with a *Rhizobium* bacteriophage, gave results in general agreement with those obtained with tomato bushy stunt and tobacco necrosis viruses. That is, there was no " multiplicity reactivation", and more infections were obtained when inoculated cultures of bacteria were illuminated than when they were in the dark. The only difference was that irradiated preparations of the bacteriophage lost infectivity after irradiation more rapidly than did control preparations (Kleczkowski and Kleczkowska).

Inhibitors of infectivity

In collaboration with Dr. G. G. Freeman of Imperial Chemical Industries, the inhibitors of plant viruses present in filtrates of *Trichothecium roseum* were studied. Inhibition is caused by two different substances, both resistant to boiling and drying. One is trichothecin, an anti-fungal substance with a molecular weight of about 300, and the other a macromolecular polysaccharide. Trichothecin is phytotoxic, and its inhibiting effect is greater with *Phaseolus vulgaris*, to which it is also more damaging, than with *Nicotiana glutinosa*. It is equally effective in preventing infection whether present in the inoculum or sprayed over the leaves either before inoculation or up to 24 hours after inoculation. The polysaccharide causes no visible injury to any plant to which it has been applied. Unlike other such inhibitors previously studied, for example, ribonuclease, it does not seem to combine with viruses *in vitro*, but it resembles these in causing inhibition only when present in the inoculum or when applied to leaves before inoculation. The extent to which it inhibits infectivity depends greatly on the species of the host plant on which tests are made and little on the identity of the virus ; it much more effectively prevents infection of *N. glutinosa* than of *P. vulgaris*, the reverse of both trichothecin and ribonuclease (Bawden).

Work was also done on the inhibiting action of sap from leaves of sugar beet, cucumber, *Datura stramonium* and *Phytolacca decandra*. Unlike the inhibitors from *T. roseum*, these are heat labile and probably proteins. Again, there is much host specificity in their action, and particularly striking is the fact that they have little effect in preventing infection of the species from which they come (Gendron).

The manner in which these inhibitors act is still obscure. It may be that they combine with the virus particles, and so prevent these from combining with essential receptor substances in the host cells, or that they combine with these receptors. Alternatively, their presence may so alter the metabolism of the host cell that introduced virus particles cannot multiply ; this theory readily explains their ineffectiveness in preventing infection of plants that contain them, because a cell would not be expected to respond to something that is normally present.

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Environment and susceptibility to infection

Some of the effects of shade and darkness in increasing the susceptibility of plants to infection with viruses have been described in previous reports. This year high temperatures have been found to produce somewhat similar effects. When plants are kept at 36°C for a day or so before inoculation, their susceptibility to infection, as measured by numbers of local lesions, is increased by factors of up to 10. Exposure to 36°C after inoculation has different effects with different viruses. With tobacco mosaic and tomato spotted wilt, effects are comparable to those obtained by putting plants in the dark, the numbers of lesions usually being rather less than those formed by control plants. With tomato bushy stunt, tobacco necrosis and cucumber mosaic viruses, by contrast, there is a great reduction in lesion numbers, and if the high temperature is maintained for a day or more, no lesions develop. Tobacco mosaic and tomato spotted wilt viruses multiply as readily at 36°C as at lower temperatures, whereas the other three appear not to multiply ; the virus content of plants systemically infected with tomato bushy stunt virus fell considerably when plants were kept at 36°C for a week or more, the fall being greater in infective virus than in the total of material serologically related to the virus.

Instead of tobacco mosaic virus being localized in necrotic lesions in *Nicotiana glutinosa* as it is at lower temperatures, at 36°C it causes chlorotic local lesions and a systemic mottle. When infected plants at 36°C are brought to 20°C, all infected tissues rapidly collapse ; as they become necrotic, scopoletin, a substance that fluoresces strongly in ultraviolet light, accumulates (Kassanis).

Variations in water supply also affected the susceptibility of *N. glutinosa* to infection with tobacco mosaic virus. Increasing the water supply increased susceptibility at all times, but did so most in spring and autumn. Differences showed within a fortnight of starting differential watering, and they were reduced by shading plants or by incorporating a diatomaceous earth in the inoculum. Although well-watered plants were more readily infected than others, tobacco mosaic virus reached a higher concentration, in both inoculated and systemically infected tobacco leaves, when plants received less water. Well-watered plants had more succulent leaves, thinner cuticles and a less regularly arranged palisade tissue, than did plants kept dry, and their greater susceptibility to infection possibly reflects the fact that they are damaged more readily and provide more entry points when inoculated (Tinsley).

When the light intensity is low, symptoms of yellows and other diseases in sugar beet plants are indistinct. In attempts to define conditions in which transmission experiments could be made reliably during winter, experiments were started to find the effects of various types of illumination on plant growth and symptoms. The preliminary tests showed that striking responses in growth were obtained in the winter with many different types of lamp, provided these gave 200 or more foot candles at pot level. The general applicability of these tests, however, is uncertain, because the diurnal fluctuations of temperature in the houses were unusual, the temperature being greater at night when the lamps were on than in the middle of the day (Nixon and Watson).

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Electron microscopy

Previously we have reported the presence of rod-shaped particles in sap from plants infected with cucumber mosaic virus. Very few were found, but as none had been seen in extracts from uninfected plants, it seemed likely that they were virus particles. Dutch workers, however, have pictured spherical particles with diameters about 75 mμ for this virus. Much work has been done in attempts to resolve these differences, but with little success. Many different plants infected with a range of different strains of cucumber mosaic virus were examined without finding any characteristic particles that could with certainty be identified as virus particles. It seems likely that the rods described previously, although we have still not found them in extracts from healthy plants, are cellulose, and the only particles resembling those described by the Dutch workers seem to be chloroplast fragments.

Similarly, no particles could be identified as virus particles in extracts from plants infected with tomato spotted wilt virus; smear preparations from plants infected with this, and with some other viruses, frequently contain chloroplasts or chloroplast fragments, whereas smears from uninfected plants do not (Bawden and Nixon).

Sugar beet plants with yellows contain characteristic filamentous particles, but the relationship of these with infective particles and with the antigen specific to infected plants still remains obscure (91). The antigen content of infected plants is now several times higher than with the strains current some years ago. Using the specific absorptive capacities of montmorillonite, much material can be removed from sugar beet sap without greatly reducing the precipitin titre with virus antiserum. This has permitted better electron micrographs of the filaments than were previously obtained; it also alters the type of precipitates with antiserum from dense granules, apparently somatic type, to more diffuse floccules, apparently flagellar type (Blencowe and Nixon).

In collaboration with members of the Pedology Department, samples of clays, allophane and synthetic iron oxide were examined (Nixon).

Radioactive isotopes

Various methods were tested for the production of tobacco mosaic virus labelled with P^{32}. The most satisfactory method for obtaining virus with a high activity was to inoculate leaves and then float them on solutions containing radio-active phosphate. More concentrated solutions of the isotope could be used in this method than when plants were grown in water cultures, for high concentrations then caused root damage and prevented normal uptake.

When healthy plants were inoculated with labelled virus, and then later macerated, some of the P^{32} was associated with materials other than the virus. Attempts were made to use the labelled virus to find how diatomaceous earths act in facilitating infection. Virus was inoculated to opposite halves of leaves with and without " Celite ", the leaves washed thoroughly and then assayed for radioactivity. The half leaves rubbed with " Celite " contained only a little more than the others, a difference far too small to account for

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the increase in numbers of infections of fifty or more times produced by using " Celite " (Bawden, Kassanis and Nixon).

In collaboration with the Bee Department, P^{32} was also used to find how rapidly and to what extent food introduced by foraging bees was distributed throughout the population of a hive (Nixon).

Sugar beet viruses

Six sugar beet viruses are being studied : (1) Sugar beet yellows virus (S.B.Y.), the strain originally isolated from Rothamsted farm and used in all transmission studies up to now ; (2) S.B.Y., Necrotic strain (N.), isolated from a severely affected field plant in 1948 ; (3) Irish mild yellows (I.M.S.) ; (4) " 41 " yellows, also from Ireland ; (5) Yellow-net virus, isolated from a field plant ; (6) Yellow-net mild strain (Y.N.M.S.), a strain separated from (5). S.B.Y. and N. precipitate with a common antiserum, and plants infected with S.B.Y. cannot be made to produce N. symptoms. None of the other four viruses has precipitated with S.B.Y. antiserum, and none of them protects plants against S.B.Y. or N.

S.B.Y. and N. have been studied in fodder beet and in *Chenopodium foliosum* and *C. capitatum*, which have been stated to be superior hosts for work on purification and serology. Extracts from these plants, however, gave no higher serological titre than from sugar beet infected at the same time, and the two wild species were so stunted that the yield of sap was greatly reduced. The N. strain killed these two species a few weeks after symptoms appeared.

" 41 " yellows virus was seed-transmitted in Kleinwanzleben E. variety of sugar beet. To gain further information on the possible relationships between " 41 " and I.M.S., breeding experiments were started to see whether I.M.S. virus is also seed-transmitted in any variety of sugar beet.

The factors affecting the transmission of Yellow net and Y.N.M.S. viruses by *M. persicae* were studied. Yellow net behaved qualitatively like S.B.Y. virus, but transmission occurred less rapidly. Six aphids per plant were needed to give workable numbers of infections, and a minimum of about 12 hours (six hours infection- and six hours test-feeding) was required for transmission. Y.N.M.S. was more readily transmissible than Yellow net, but it caused less severe symptoms (Watson).

Yellows virus moved out of a sugar beet leaf inoculated by infective aphids within a few hours of the aphids being placed on the leaf. By contrast, several days elapsed before sugar beet mosaic virus moved from leaves inoculated either by aphids or by rubbing with infective sap.

A portable suction trap was devised, suitable for catching representative samples of living winged aphids in the field. The method seems practical, and it was intended to discover what proportion of the alate aphids flying were actually viruliferous, but too few aphids were caught this year.

Experiments on the effects of dates of sowing and singling on crops of sugar beet were done at Dunholme, the Norfolk Agricultural Station, and Rothamsted. Bad weather in the spring delayed sowing, but good stands were obtained, except on the late-singled plots at Rothamsted, where the stand was uneven.

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Aphids appeared later than usual, and there were few *Myzus persicae*. *Aphis fabae* were more numerous, but the peak populations of several hundred individuals per plant did not develop until mid-August, and persisted for only a short time. At Rothamsted and Dunholme there were more apterous *A. fabae* per plant on the later sown beet, but alatae were uniformly distributed on the plots sown at different times.

Few plants were infected with yellows virus and none until late in the season. Unlike the previous year, neither sowing date nor time of singling affected incidence. The yields of roots are unlikely to be influenced by yellows, and the harvested yields will give information on the effects of the treatments on healthy crops (Blencowe).

Samples from all steckling beds inspected in the autumn of 1950 were planted in plots at Dunholme. They were very healthy. None showed more than 5 per cent of plants with yellows and most were below 1 per cent. Mosaic and downy mildew were also rare.

Steckling-bed inspections were again organized in the autumn of 1951. The general level of infection with yellows is low and only one bed, which had 7 per cent plants infected, had to be discarded. The mean level of observed plants infected in the beds to be used for planting is 0·07 per cent, only about a quarter of that in 1950.

Stecklings sown in June at elevations of about 1,000 ft. in Scotland developed to a satisfactory size, but those sown in July were small. Small plants did not store satisfactorily; the larger ones stored well in various forms of clamp, but they did not in sacks kept overwinter in a shed. There were very few infected plants in any of the sowings at the seven centres. Mangolds behaved like sugar beet and grew well after storage, but none of the eight varieties survived the winter out of doors in Perthshire. Red beet, Cheltenham Green Top, failed at all centres.

Several experiments tested different methods of storing sugar beet, mangolds and red beet stecklings during the winter. All the clamping methods were successful, and the only serious failure was from storing bagged plants in a shed. In the warmest storage conditions, the stecklings sprouted and food reserves were lost from the roots (as determined by refractometer, sugar-content or soluble dry matter). A preliminary examination of the results shows a close relationship between the plant establishment and the sugar content of the roots when set out. This may prove helpful in determining whether stored plants are likely to succeed or fail.

In previous years, spraying steckling beds with systemic insecticides has been beneficial in reducing the incidence of yellows. The experiment made in 1950 was valueless, as the control plots had less than 3 per cent infected plants.

Experiments have been made under glass to see how these sprays affect transmission of yellow virus. Aphids were fed for varying periods on unsprayed and Pestox-sprayed plants infected with yellows, and were then transferred to healthy test plants (five aphids per plant). With feeding periods of 10 minutes and one hour, few infections were obtained, but the aphids from sprayed plants transmitted about as frequently as those from unsprayed plants. With feeding periods of 24 hours, however, aphids from the sprayed plants

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gave considerably fewer transmissions, and with periods of 48 hours few aphids could be found on the sprayed plants.

Infective aphids (five per plant) were also fed for periods of 2-28 hours on seedlings sprayed the previous afternoon with a mixture of Pestox III and 14, and on corresponding unsprayed plants. All the unsprayed plants except one became infected, whereas only half the sprayed seedlings did. This proportion was the same with all the feeding periods employed. Many aphids on the sprayed plants were dead by the end of the feeding period and others had walked off.

An experiment was arranged to observe the behaviour of aphids put out on sprayed and unsprayed plots and the spread of yellows from infected plants in the centre of the plots. The crop was vigorous, and the plots were singled to compare stands of different density. The aphids put out failed to produce an infestation, and in August and September there were only a very few *Myzus persicae*, which may have developed from migrants arriving in the field. *Aphis fabae* arrived in July and became numerous in August and September, producing many alatae, and they may have spread the virus. Spread from the initial centres of infection was slow, but many isolated infected plants appeared.

Infections were more numerous in plots with a low plant population, which although they contained only half as many plants as the closely spaced plots, contained twice as many infections per unit area. Spraying halved the number of infected plants.

Plots were infected artificially at three different times with a mild and a severe strain of yellows virus. There were pronounced differences in the effects of the virus strains, both on rate of symptom development and on yields (Cornford, Gates and Hull).

Potato viruses

Various manurial treatments in 1950 had no significant effect on the spread of leaf roll virus, but dung significantly increased the spread of potato virus Y. Both viruses spread more in plots planted on March 31st and April 21st than on May 12th and June 2nd.

The results of ten experiments made in 1950 in co-operation with the National Agricultural Advisory Service, eight in potential seed-growing areas of England and Wales, and two in other areas, showed that the time when winged *M. persicae* is active is very important in determining the spread of virus diseases. The ratio, spread of viruses to numbers of trapped aphids, was much greater early in the year than late. Potatoes in seed areas were colonized by aphids later than in the other areas.

In a small preliminary trial, made in 1950 to test the effects of insecticides on the spread of potato viruses, virus Y increased in plots receiving different treatments by the following factors: Control $\times$ 31; E. 605 $\times$ 19; Toxaphene $\times$ 19; Pestox III $\times$ 22; Dieldrin $\times$ 26; D.D.T. $\times$ 37. There was some reduction with all treatments except D.D.T., which apparently irritates aphids and causes them to move more frequently than they would do otherwise. Leaf roll virus spread little in any plot.

The experiments in co-operation with the National Agricultural Advisory Service were repeated in 1951. At Rothamsted, as else-

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where, *M. persicae* was late in colonizing the crops, and no large population developed. *Aphis rhamni* was the most numerous aphid on potatoes at Rothamsted. The late appearance of *M. persicae* was remarkable, for other aphids were common. To the end of June 10,000 aphids were caught on 16 traps in different parts of England and Wales, but no *M. persicae* or *Brevicoryne brassicae*. Apparently *M. persicae* failed to overwinter viviparously on outdoor plants.

In 1951 a large experiment was done in co-operation with the Insecticides Department. Plots of potatoes containing a known number of virus-infected plants were sprayed every ten days from emergence to maturity with D.D.T., Parathion, Isopestox, Dieldrin or Toxaphene. The insecticides prevented the development of aphid populations, but their effect on virus spread will not be known until 1952. (Broadbent and Tinsley.)

Viruses of cruciferous plants

Preliminary tests suggested that, in addition to *Myzus persicae* and *Brevicoryne brassicae*, cauliflower mosaic virus could be transmitted by *Acyrthosiphum pisum*, *Aulacorthum sonchi*, *Nacrosiphum euphorbiae*, *Aphis fabae*, *Macrosiphum rosae* and *Nasonovia ribisnigri*, and cabbage black ringspot virus by *A. pisum*, *A. fabae* and *M. rosae*. Whether these other species play any part in spreading the viruses in field crops is unknown. As on potato and sugar beet crops, there were fewer aphids than usual on cruciferous crops in 1950 and viruses spread extensively only near allotments or seed plants. Cauliflower mosaic virus was more prevalent than black ringspot ; it also usually causes the more severe disease, but generalizations are difficult because both viruses occur in strains that differ in virulence towards different species and varieties. In general, symptoms caused by cabbage black ringspot virus are prominent only on the lower leaves of infected plants, and growth is not seriously affected, even in cabbage, kale and the cauliflower varieties that react clearly. Cauliflower mosaic virus causes severe diseases in turnip, and most, but not all, cauliflower varieties ; it is moderately severe in kale and mustard, but is tolerated by cabbages and Brussel sprouts. Weekly sprayings of a cauliflower seed-bed with D.D.T., parathion and Isopestox did not significantly reduce the incidence of cauliflower mosaic (Broadbent and Tinsley).

Cauliflower mosaic virus is more stable than cabbage black ringspot, thermal inactivation point 70° compared with 60°, and longevity *in vitro* of six days compared with two. For both viruses, turnip plants were more easily infected than other hosts and provided the best source of virus in insect-transmission work. Both viruses are " non-persistent ", and are transmitted more readily when aphids are starved before they feed on infected plants. Most work has been done on cabbage black ringspot virus, using tobacco as a test plant, because it produces local lesions and gives quantitative results. Preliminary starving for 15 minutes increased transmission, but increases in the period of starving from 1 to 16 hours did not increase it further. When aphids were kept at 4° at the start of the period of fasting, a smaller increase was obtained in the number of transmissions than when they were starved at 17°, or

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were first starved at 17° and then at 4° immediately before the infection feeding. Increasing the numbers of aphids per test plant proportionally increases the number of transmissions, showing that individual aphids do not give sub-minimal effects that accumulate to cause infection. Small quantities of infective sap lost infectivity at approximately the same rate at which infective vectors lost infectivity when starved for 6 hours. (Hamlyn.)

Mycology

Spore dispersal

Work has been continued on the dispersal and deposition of spores, both in the open and in the wind tunnel. The deposition in wind-tunnel tests of spores on cylinders of various sizes has been described (86), and attention has been turned to deposition on plane surfaces. This proved unexpectedly complex, and the phenomena encountered await interpretation by aerodynamicists. The results, however, do permit the first reasoned analysis of the spore-trapping methods employed by plant pathologists and allergists. At the commonest wind speeds (below 5 m.p.h.) the horizontal slide as normally used greatly under-estimates the atmospheric concentration of spores, because the edge of the slide modifies the air flow. At high wind speeds (above 10 m.p.h.), spore concentrations are over-estimated, because turbulence increases deposition (Gregory).

One outcome of this work has been the designing, making and testing in the wind tunnel of a greatly improved spore trap (88). This has been successfully used in the field to measure the daily variations in atmospheric spore concentrations. The variations are large and occur in all kinds of weather ; rain reduces the numbers of spores common in dry weather, but leads to the appearance of other types. Over potato crops, sporangia of *Phytophthora infestans* were trapped in quantity only between 08.00 and 18.00 G.M.T., with peak concentrations between 09.00 and 12.00. This suggests that conditions before noon may be an important factor affecting the spread of potato blight, but further work with traps at different heights is needed before definite conclusions can be reached (Hirst).

The atmospheric spore concentrations during 1951 were generally low, for powdery mildews the lowest since trapping started in 1947 ; there were few uredospores, but *Cladosporium* sp. were plentiful and there were heavy showers of smut spores (probably *Ustilago perenanns*) in June (Gregory, Hirst and Last).

Sooty bark of sycamore

Work on this disease, in collaboration with Mr. S. Waller, was continued. The fungus has been described and transferred to a new genus as *Cryptostroma corticale* (87). In addition to observing naturally infected trees, transmission tests were made using spores taken direct from affected trees and mycelium from single-spore cultures. Cut branches to which spore suspensions were applied produced, more often than not, typical stains and sporing lesions within twelve months. A tree inoculated with a pure culture also became typically stained, but it was felled before it spored (Gregory).

Mushroom mummy disease

An outbreak of mummy disease in Yorkshire presented the

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opportunity to study this disease, which American workers have suggested may be caused by a virus. Dr. I. F. Storey provided soil and compost from affected beds and, when added to boxes immediately before fruiting, this successfully transmitted the disease. None of our experiments has given results suggesting that it is a virus disease, and some of our results suggest that it is not. Extracts from mummy mushrooms have been added to compost with spawn and with fruiting bodies, and have been inoculated to young " buttons", without reproducing the disease. Pure cultures of the fungus were established on agar media, from pileus tissue and from spores, of both normal and mummy mushrooms. Composts in 8-inch pots were successfully inoculated with these cultures, and with spawn derived from them and grown on wheat grains, but all gave normal mushrooms. Thus the disease appears not to be caused by a virus that is present within the hyphae or spores of affected fruiting bodies. The cause remains undetermined, but seems more likely to be some agent present in the soil that is not perpetuated within the mushroom mycelium (Bawden and Gregory).

Cereal mildews

Powdery mildews were less common than usual, but there was enough on the Broadbalk crop in July to show the importance of manuring in affecting its incidence. The least heavily infected plots were those that were unmanured, or received dung or phosphorus and potash only, and the most heavily infected were those that received 4 and 6 cwt. of ammonium sulphate and 5 cwt. of sodium nitrate in the spring. Fallow also greatly increased the incidence of mildew, the plots on ground fallowed the previous year having a mean number of pustules almost twenty times as great as the others. The effect persists for one year only.

Pot experiments also showed the dependence of infection on the nitrogen status of the host plants and their rate of growth. Plants deficient in nitrogen were highly resistant but became susceptible within ten days of receiving nitrogen. Growth responses to nitrogen were paralleled by increase in numbers of infections, the curve for the second duplicating the first, but with a lag of ten days (Last).

Cereal foot and root rots

A rotation experiment, begun three years ago, was ended, and the whole area cropped with winter wheat. The effects of two years under different crops in freeing land from eyespot, take-all and weeds, which were prevalent in the sixth successive wheat crop in 1948, were tested. Non-susceptible crops were grown in 1949. The 1951 winter-wheat crop followed winter-wheat, barley, oats and spring-sown ryegrass, and 68, 55, 21 and 7 per cent straws had eyespot at harvest; in April, take-all was severe on the roots of 21, 12, 0, 0 per cent plants, and at harvest weeds covered 13, 3, 1, 2 per cent of the plots. Thus, after non-susceptible crops, oats and spring-sown ryegrass eliminated take-all and greatly reduced eyespot. Yields are not yet known, but the beneficial effects of controlling disease and weeds were evident.

In winter-wheat, grown outdoors in pots for the third successive year in the same soil, eyespot reduced mean yield of grain by 44

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per cent in unsprayed and by 9 per cent in plants sprayed with H_2SO_4 in spring. Spraying reduced yield of uninfected plants by 13 per cent and increased that of infected ones by 42 per cent. Take-all increased each year and was not affected by spraying. It decreased with increasing applications of ammonium sulphate and increased with increasing seed rate. The extremes were strongly contrasted; in the most thickly sown pots which received no ammonium sulphate, 98 per cent of the plants were severely infected and the roots destroyed; the mean grain yield was 0·8 gm. per pot; in thinly sown pots receiving the heaviest doses of ammonium sulphate, the plants had good roots with no take-all and the mean grain yield was 17·1 gm. per pot. (Glynne and Salt.)

The effect of applying nitrates to winter-wheat at different stages of growth was again studied. Nitrogen applied to uninfected plants at any time before growth had been checked by nitrogen starvation, produced equal increments of grain. Loss in yield caused by eyespot was most reduced by nitrogen applied in March, when it could be most efficiently used by the plant. Thus, equal increments of grain (+ 18·7 gm) were obtained by applying 0·5 gm N. per pot to uninfected plants between November and March, but smaller yields were obtained with April (+12·9) and May (+5·2) applications. Pots without nitrogen yielded only 2·0 gm. By applying 0·1 gm N. at sowing and 0·4 gm later, tillers survived for a longer time and a high yield was obtained with the April (+17·4) and also with the May application (+14·2).

The application of 0·5 gm N. in November, January, March, April and May reduced loss in yield from eyespot from 99 per cent to 25, 34, 18, 39 and 62 per cent, and reduced the percentage of severely infected ear-bearing straws from 100 to 24, 48, 11, 30 and 79, respectively. The application of 0·1 gm N. at sowing and 0·4 gm subsequently, further reduced the loss from eyespot to 22, 25, 11, 28 and 51 per cent for the five dates of application, although the per cent of severely infected straws was not similarly reduced. (Salt.)

On plants grown to maturity in soil in 7-inch pots, two isolates of *Cercosporella herpotrichoides* from wheat, and one from oats, penetrated wheat leaf sheaths more rapidly than barley and caused more severe lesions; they penetrated leaf sheaths of oats and rye more slowly, and caused less severe lesions by harvest. Mean loss in grain yield was 39 per cent in wheat, 22 per cent in barley, and was negligible in oats and rye. These results accord with field observations on relative susceptibility. By contrast, when plants were grown in washed sand, wheat and rye were pentrated more quickly than barley and oats.

An earlier pot experiment showed rye grown in soil to be less susceptible than oats to an isolate from wheat. In Denmark, however, rye seems to be more susceptible than oats. Isolates were therefore obtained from wheat and rye at Lyngby, and compared with those from wheat and oats in England. Both in soil and sand, the isolate from rye penetrated more slowly into wheat and barley and much more quickly into rye than the other three isolates. Differences between susceptibility of oats and rye in England and

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in Denmark, therefore, may reflect differences in the strains of the fungus prevalent in the two countries.

When plants grown in sand were inoculated with *Corticium* (*Rhizoctonia*) *solani* the fungus attacked wild oats (*A. fatua* and *A. ludoviciana*), and killed many seedlings of rye and oats; it attacked wheat and barley much less severely (Glynne).

Potato blight

Work was started on the survival of *Phytophthora infestans* in potato tubers. Naturally infected King Edward tubers from a 1950 field crop were stored in boxes, and planted under glass in the spring of 1951. Out of twelve plants that produced shoots in March, six developed blight lesions on one or more shoots. No lesions appeared after mid-April on these plants, probably because the high temperature in the glasshouse killed the fungus.

The effects of climate on potato blight, and the value of warning systems based on temperature and humidity data, were tested by taking continuous readings with wet and dry bulb thermographs kept in (1) a Stevenson screen at 4 feet above ground, (2) level with the tops of ridges on bare ground and (3) in potato crops. The conditions of a " Beaumont period", 48 hours with temperature not falling below 50°F and relative humidity above 75 per cent, were needed for blight to occur; these conditions sometimes happened within the crop but not in the screen, and the screen records were, therefore, less reliable in forecasting outbreaks.

Small plots of the potato varieties Canso and Keswick, bred in Canada for resistance to blight, were grown; both varieties developed blight about a month after its appearance on surrounding plants of the variety Majestic. Dr. M. A. Keay of the Potato Genetic Station, Cambridge, had previously tested the varieties and found them resistant to strains A and C, but not B, and she identified the strain attacking them in the field as one of the B forms. (Hirst.)

Clubroot of cruciferous plants

The factors affecting the survival of *Plasmodiophora brassicae* in the soil and the production of clubroot (90) were further studied. Contrary to previous results, varying the time at which nutrients were applied did not affect the numbers of clubs produced, but, as before, increased manuring increased them. The effect is probably a simple reflection of the increased growth of the plants produced by heavier manuring.

Increased attention was given to techniques for studying spore germination and infection in laboratory conditions. Methods are still being developed and cannot yet be regarded as satisfactory, but some progress was made. Many root-hair infections were obtained by growing cabbage seedlings in small horizontal tubes containing spores in a dilute solution of mineral nutrients. Seedlings infected in this way were transferred to larger water-culture vessels and some produced clubbed roots. The chief difficulty in getting this result is to grow the cabbage plants so that the infected epidermal cells do not die before clubbing occurs.

Spores removed from the small tubes in such experiments were examined and sometimes many empty (germinated) spores were

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seen. Standing drops of spore suspension were more convenient for quantitative observations on germination, because counts can be made on the spores *in situ*. Germination has sometimes occurred readily under these conditions, but results were highly erratic, for unknown reasons. Germinating spores were seen, and the zoospores emerged through small pores in the spore wall. (Macfarlane.)

Sugar-beet downy mildew.

Work was continued on the factors affecting the incidence and spread of sugar-beet downy mildew. Many affected plants are killed by frost, and the disease is most prevalent after mild winters and when the monthly rainfall from June to September is between 1·5 and 3·5 inches. Isolation from seed-crops and other overwintering sources of the fungus is the simplest control measure and serious outbreaks are rare at distances of more than half a mile from such sources.

Seedlings are readily infected and plants become increasingly resistant as they age. In dry air spores remain viable for periods up to two weeks. In damp air, some germinate within a few hours, others take several days ; the proportion that germinates, and the time at which they do so, varies widely with different batches. In damp air, the spores remain attached to the coniophores, but in dry air they are readily detached. (Cornford.)

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