ROTHAMSTED RESEARCH

Report for 1953

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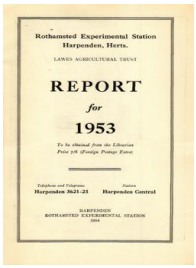

Plant Pathology Department

F. C. Bawden

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PLANT PATHOLOGY DEPARTMENT

F. C. Bawden

We had hoped to have a full season's use of the new insectary and glasshouses, but building delays meant that we did not start to use them until October. These, with the extension to the potting sheds and a new animal house, are valuable additions to our facilities, but we cannot yet report on the ventilation and other features of the glasshouse. The Dunholme Field Station was also improved by installing central heating in the laboratories and building a small seedling house.

F. M. Roberts resigned in September to join the Colonial Agricultural Research Service, and is now studying the "unknown disease" of coconuts in Jamaica. T. W. Tinsley's period of secondment to the West African Cacao Research Institute was extended for a further tour of eighteen months.

F. C. Bawden attended the International Congress of Microbiology at Rome in September, and, as the guest of the organizing committee, took part in a symposium on the *Dynamics of Virus Infection*, held in October at the Ford Hospital in Detroit. R. Hull visited Holland and West Germany in September, to see large-scale experiments to test the value of insecticides in controlling beet yellows. He also attended the meeting of the International Institute of Sugar Beet Research at Bergen op Zoom in December; so, too, did J. W. Blencowe, who spent some time studying the serological techniques used by Dutch workers with plant viruses.

G. A. Salt was awarded the degree of Ph.D. of London University.

Viruses and Virus Diseases

Variations in infectivity of virus preparations

In previous reports we have commented on the variable infectivity of preparations of the Rothamsted tobacco necrosis virus (RTNV). Preparations made by sedimenting the virus from freshly extracted sap are, weight for weight, less infective than preparations made by centrifuging sap that has aged for a day or so at room temperature. This difference seemed to suggest that virus particles could acquire infectivity *in vitro*, but further work makes this idea less likely. It now seems probable that infective sap contains an enzyme that can destroy infectivity without destroying the physical integrity of the virus particles. The enzyme is unstable in sap and has little effect on the virus in sap, but it sediments with the virus when fresh sap is ultracentrifuged, and is stable and active in partially purified preparations of RTNV.

Workers in the U.S.A. have reported that sap from plants infected with tobacco mosaic virus (TMV) contains, in addition to specific nucleoproteins, proteins that have the serological characters of the virus but that contain no nucleic acid. As yet we have not identified any such particles, though we have several times sought

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them. We have confirmed our earlier conclusions that sap contains specific particles of various sizes and that the small ones have little or no infectivity, but we are now finding that the ratio of small to large particles in fresh sap is much smaller than we recorded some years ago. (Bawden and Pirie.)

The rate of virus multiplication

As a preliminary to studying the factors that affect virus multiplication, detailed experiments have been made on the rate at which viruses multiply in inoculated leaves. Assays on extracts from leaves macerated at different times after inoculation show the same three phases with all viruses and hosts studied. First, there is a period during which infectivity decreases; this is followed by a period of rapid increase, which passes into a third, during which infectivity still increases, but at an increasingly slower rate. The shortest time after inoculation at which newly-formed virus was detected varied with different viruses and host plants. At 20–25° C., it was 10 hours for RTNV in French bean, 24 hours for RTNV in tobacco and 40 hours for TMV in tobacco and *N. glutinosa*. Experiments in which inoculated leaves were exposed to ultraviolet radiation, suggest that these times are probably at least twice the minimum required for new virus to be formed. As reported last year, irradiation appears to affect virus only when it is in the epidermal cells. Irradiation 6 hours after inoculation halves the number of infections produced by RTNV in French bean, and irradiation after 20 hours halves the number produced by RTNV and TMV in tobacco. These times are thought to indicate the time required for the inoculum to multiply in the epidermis cells and new virus to pass from there to deeper cells; this move seems to occur before free virus can be detected in leaf extracts. With RTNV in French bean, the times needed for successive ten-fold increases in infectivity of leaf extracts, starting 19 hours after inoculation, were 3, 7, 10 and 19 hours. During the first day after inoculation, virus multiplies predominantly in the epidermal cells, but after this most is produced in the chlorenchyma. (Harrison.)

Heat therapy

Last year we reported that growing plants at 36° could be used to establish virus-free progeny from parent plants systemically infected with tomato bushy stunt and a carnation virus. Many cuttings taken from side shoots or the main stem of plants kept continuously at 36° for ten or more days developed into healthy plants. The result has been confirmed and the work extended to other viruses, most of which seem to multiply poorly at 36° and many, including some with high thermal inactivation points, not enough to maintain themselves. Virus-free progeny were established from variegated *Abutilon*, and from plants infected with cucumber mosaic and tomato aspermy viruses. With the last two, striking cuttings was not always necessary, for many of the heated parent plants themselves were wholly freed from the infecting viruses and remained healthy when kept for months in ordinary glasshouse conditions. No healthy plants were established when cuttings were taken from treated plants infected with tobacco

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mosaic, potato X or tomato spotted wilt viruses, though the virus content of plants kept for fourteen days at 36° was much less than that of comparable plants at 20°. (Kassanis.)

Electron microscopy

Electron microscopy has continued to be used in the routine examination of virus preparations, but most time has been occupied in improving techniques, particularly for preparing sections of leaf cells. When clear pictures of tobacco mosaic virus were obtained in sections from infected leaves, attempts were made to use electron microscopy to discover the sequence of events involved during infection. These failed, partly because sections contain only parts of a few cells and, in the early stage of infection, the virus occurs in detectable quantities in only a small proportion of the cells. Also, although with winter-grown plants fixation was good enough to identify virus particles in the cytoplasm, it was not good enough to do so in such structures as chloroplasts. With the harder cuticle of summer-grown plants, fixation was worse, and treatments were sought that might help the fixative to penetrate without damaging the cell contents. Of many treatments tried on intact pieces of leaf, the best was rinsing in 10 per cent " Teepol ", but still better results have been obtained recently by removing one epidermis before putting the leaf in fixative. This method has shown that the buffer containing the osmium tetroxide fixative affects fixation, and that the chloroplasts are better preserved if the leaves are left in fixative for 24 hours instead of for 2, as was the previous practice. The nuclei, however, are better preserved with the short exposure to the fixative. Dissolving the plastic embedding material is a slow process, and also seems to harm delicate structures in the cells; by cutting sections thin enough (0·05 μ or less), and modifying the microscope suitably, the plastic can be left in place without obscuring fine details.

The spray method devised by Backus and Williams for counting particles has been modified to produce small drops. An " Aerograph " spray gun makes a satisfactory substitute for their glass spray with concentric jets, which is difficult to make accurately. The drops from the gun are sorted and collected in a " Cascade Impactor ", instead of being allowed to sediment erratically on grids placed 30–40 cm. from the spray. By this method small drops (1–2 μ across) can be selected, and this allows examination at the high magnification needed to count the small particles in preparations of RTNV. Some of the larger particles in preparations of this virus seem to become flattened by surface tension when the droplets dry, and the method is now being adapted to combine the advantages of collecting drops by impaction with rapid freeze-drying. This technique also promises to be valuable for examining the structure of clay aggregates by electron microscopy. (Nixon and Fisher.)

Effects of ultra-violet radiation on proteins

To compare their behaviour with that of viruses, antibodies and chymotrypsin were irradiated with ultra-violet light. The inactivation of both follows the course of a first-order reaction.

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The quantum yield for antibodies is about 10^{-3}, falling between the value for viruses and smaller proteins, further evidence that quantum yield and particle weight are inversely proportional. This fact suggests that the same amount of radiation energy must be adsorbed by each unit weight of a protein to inactivate specific biological activities. In some conditions irradiated antibody combines with other serum proteins to form complexes, which, although they still combine specifically with their antigens, behave differently from normal antibodies in precipitin tests. As with complexes formed when antisera are heated, the behaviour of the irradiated antisera depends on the character of the antigen. Unlike the plant viruses studied, but like a *Rhizobium* bacteriophage, chymotrypsin that is still active after exposure to ultra-violet is less stable than unexposed enzyme. When tobacco mosaic virus is exposed to much more radiation than is needed to destroy its infectivity, its resistance to denaturation by heat is decreased.

Ribonuclease and chymotrypsin, both of which inhibit infections by plant viruses, also inhibit infections of *Rhizobium* sp. by bacteriophages. The two enzymes seem to act in different ways. Chymotrypsin does not interfere with the combination between virus and bacterium, but interferes with some process that occurs immediately after they combine, whereas ribonuclease interferes both with the combination and also slows the growth of the bacteria. (Kleczkowski.)

Virus diseases of carnation

Most commercial stocks of common carnation varieties seem to be virus-infected, but the viruses concerned and their relative importance have been little studied. Infected carnations often show no clear leaf symptoms, but their infected state is usually shown by inoculating sap from them to sweet william (*Dianthus barbatus*) plants, which are hosts of all the carnation viruses and react to most by showing much clearer symptoms than do carnations. One virus, widely distributed in carnations, will infect tobacco and French bean, but these species rarely become infected when inoculated with sap from infected carnation or sweet william plants, because the sap contains substances that strongly inhibit infection of both tobacco and French bean.

Four distinct viruses have been isolated from commercial stocks of carnations. Two (including the one that infects tobacco and French bean and has previously been recorded in Holland) have spherical particles, a thermal inactivation point above 80°, are easily purified, and plants can be freed from them by exposure to 36° for fourteen days. No insect vector has been found for either. The other two viruses have elongated particles, a thermal inactivation point below 65°, and both are transmitted by *Myzus persicae*. Growing plants at 36° has not freed plants from either. The existence of one of these was recognized solely from serological tests and electron microscopy. It produces no external symptoms in either carnation or sweet william, but its transmission to and multiplication in them can be detected serologically or by examining sap in the electron microscope. Sugar beet has recently been found to be susceptible, and this plant is the only one yet discovered that shows symptoms of infection, the older leaves sometimes

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becoming chlorotic. Whether this virus occurs in field crops of sugar beet is unknown. (Kassanis.)

Viruses of cruciferous crops

Studies on the transmission of cabbage black ringspot (CBRSV) and cauliflower mosaic (CLMV) viruses, by *Myzus persicae* and *Brevicoryne brassicae*, showed considerable differences between the behaviour of the two viruses and slight differences between the two aphids. Most infections with CBRSV and *M. persicae* were obtained when previously fasted aphids were fed for 2 minutes or less on infected plants, but the numbers of *B. brassicae* that transmitted increased with infection-feeding times up to 30 minutes, after which they decreased. With short infection-feeding times more *M. persicae* than *B. brassicae* transmitted, but with infection-feeding times of 1 hour or longer, equal numbers of both species transmitted. *B. brassicae* ceased to be infective within 2 hours of leaving infected plants, whereas *M. persicae* remained infective for 6 hours when fasted. More aphids of both species transmitted CLMV when given infection-feeding times of 1 hour or more, than when given infection-feeding times of 2 minutes. With the 2-minute infection feedings, the proportion that transmitted was increased if the aphids were previously fasted, but even so, it was less than with prolonged infection feedings. Experiments with leaves exposed to ultra-violet radiation suggests that CBRSV occurs in greater concentration in the epidermis than in other cells of infected leaves. The differences between the behaviour of the two viruses suggest that CLMV is more uniformly distributed through the various tissues of infected leaves. The differences between the behaviour of the two species of aphids in transmitting CBRSV can be partially explained by the asumption that fasting affects their feeding habits differently, and that *M. persicae* after fasting are more likely to imbibe sap from the epidermis. Fasting aphids can still infect healthy plants with CLMV as long as 6 hours after leaving an infected plant. *Myzus circumflexus* transmitted CBRSV from infected turnip to tobacco. (Watson and Hamlyn.)

Field experiments in conjunction with the National Agricultural Advisory Service were done in different parts of the country to see how the incidence of virus diseases was affected by surrounding cauliflower seed beds with narrow strips of barley, kale and broad beans. Aphids were so few in the spring that there was little spread of CLMV or CBRSV, but wherever the viruses occurred, their incidence was decreased by the barriers, particularly of barley. Seedlings surrounded by barriers grew better than unprotected ones, and up to 10 per cent more plantable ones were obtained.

Winged aphids produced on plants infected with CLMV were collected as they migrated, and were placed singly on turnip seedlings to see what proportion was infective. Of 191 tested, thirty-five infected the turnips.

A new form of sticky aphid trap was constructed to be used for a survey of virus diseases of cauliflower crops that the National Agricultural Advisory Service is making. The sticky surface is horizontal and placed level with the surface of the crop; comparisons with the old type of cylindrical trap suggest that it will

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give a truer picture of aphids entering, leaving or moving within the crops, for the older type of cylindrical trap mainly caught wind-borne aphids.

Plots of various crops were again grown and regularly observed for their populations of *Myzus persicae* and other aphids. The results so far obtained, with all species recorded, agree with those reported by Kennedy with *Aphis fabae*, in showing that aphids preferentially infest tissues that are either rapidly growing or becoming senescent.

The multiplication of *M. persicae* on healthy and virus-infected cauliflower plants was compared by infesting caged plants and counting the aphids one month later. Although four times as many aphids were produced on the infected plants, the difference was barely significant, because the variations between individual plants were so large.

Turnip yellow mosaic virus was diagnosed in several kinds of cruciferous crops, and did much damage in Northumberland. Some of the isolates of this virus seem to differ from those previously described. (Broadbent and Heathcote.)

Potato virus diseases

As in previous years, the overhead irrigation of potato crops did not significantly affect the spread of potato viruses.

In a field experiment done in conjunction with the insecticides Department, Majestic potatoes were sprayed with five insecticides. Late in July, the unsprayed plots developed the largest population of *M. persicae* recorded at Rothamsted for many years, but none of the sprayed plots became infested. Effects on the spread of viruses will not be known until 1954. Excellent control of aphids was also obtained by spraying two commercial potato crops in Essex, the second year of a test to see whether insecticides will prolong the useful life of seed stocks there. When planted, the stocks were free from leaf roll and severe mosaic, but in the second year 1 per cent of the plants had leaf roll; 2 per cent in one crop, and 5 per cent in the other, had severe mosaic. These diseases occurred to the same extent whether the plots were sprayed or not in 1952. As expected, the insecticides did not prevent viruses from being introduced into healthy crops, and it will not be known until next year whether they affect the spread from infected plants within the crop. Further information on this series of experiments on virus control is given in the report of the Insecticides Department. (Broadbent.)

Sugar beet virus diseases

Experiments were started to devise methods for assessing the relative susceptibility of sugar-beet varieties to yellows. Twenty varieties supplied by the Plant Breeding Institute, Cambridge, were tested by colonizing thirty seedlings, ten each being colonized with one, five and ten aphids. The properties of the plants that developed symptoms was taken as an index of susceptibility, and the severity of symptoms was also recorded to give some measure of tolerance. Varieties from *Beta maritima* showed less severe symptoms than *Beta vulgaris*, but both types were equally susceptible to infection.

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Serological tests showed that *B. vulgaris* plants also contained more virus, and *B. maritima* plants with more severe symptoms contained more virus than those with mild symptoms. Plants with slight symptoms in the glasshouses often became severely chlorotic when grown in the open, whereas seedlings that had shown severe symptoms sometimes recovered when grown in the open, the appearance of recovery being helped by the death of the yellow leaves. (Watson.)

Experiments at Dunholme comparing the reaction to yellows of inbred lines of sugar beet also sometimes gave different results when comparisons were made between seedlings in glasshouse or plants in the field. Line M9, for example, reacted severely in the glasshouse, but in the field was greener and less stunted than N4, which in the seedling stage under glass showed only very faint symptoms. Reductions in yield of sugar from infection reflected the severity of symptoms shown in the field. Thirty-seven inbred American lines of beet were all found to be susceptible. A comparable range of reaction to infection was noted as in our inbred lines. Whereas seedlings of some lines showed etching of the veins rapidly and soon became necrotic and stunted, seedlings of other lines took much longer to show symptoms, which then were also usually milder, some giving only restricted yellow blotches on a few leaves. (Hull.)

The study of viruses isolated from beet showing symptoms of different type and severity suggests that there may be more than one cause for the disease normally called " yellows " in field crops. Many isolates have been found that cause yellowing but no etch or other necrotic lesions, and sap from plants infected with these has consistently failed to react with antisera prepared against isolates that cause necrosis. Similarly, when sap from diseased plants has been examined with the electron microscope, filamentous particles have been found only when the plants showed necrotic symptoms and when their sap precipitated strongly with antiserum. Plants showing yellowing only developed veinal necrosis as rapidly as previously healthy plants when they were infected with virus from plants with necrosis. Plants so infected were more chlorotic and stunted than were plants infected with either isolate alone. Whether the isolates that cause these different effects are distinct viruses or related strains remains to be established; those causing necrosis occur together in the same crops and often in the same plants as those that do not. All seem to be transmitted similarly by aphids. (Hull and Blencowe.)

The series of field experiments on the effects of date of sowing and time of singling sugar beet was finished. Again only a small percentage of the plants contracted yellows, and they not until after the latest singling. In nine experiments done at Rothamsted, Dunholme and the Norfolk Agricultural Station, Sprowston, between 1950 and 1953, only once has the time of singling greatly influenced the incidence of yellows. On that occasion there was an unusually early migration of aphids, and a much smaller proportion of the plants became infected on the plots which had not been singled. The incidence of yellows has usually been affected by date of sowing. In years when aphids arrived early, plots sown in March had more plants infected than did plots sown in May. More usually, however, the aphids arrived in late June or July, and then the late-sown beet had more infected plants than the early-sown.

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The May-sown beet also had larger populations of apterous aphids, especially *Aphis fabae*.

Late singling decreased plant populations and yields unless "rubbed" or "de-corticated" seed was used. Sowing seed in March usually gave the biggest yields, except when weather caused much "bolting". (Blencowe.)

Samples from all beds of sugar-beet stecklings sown in the United Kingdom were planted at Dunholme. Those used for planting commercial seed crops in June averaged 2·6 per cent plants with yellows. Steckling beds in the north of England had exceptionally heavy aphid infestations, and they had a mean of 4·1 per cent infected plants, compared with 1·9 per cent for beds in the Eastern Counties sprayed with insecticide and 1·3 per cent for beds grown there under a cover crop and sprayed. Seven beds were rejected because they had more than 1 per cent infected plants in the autumn. Samples from six of these beds gave from 6 to 63 per cent infected plants. Nine beds passed for planting gave 5–10 per cent infected seeders, three 10–15 per cent and two gave 22 per cent. Most of these were from beds in the north.

In the autumn of 1953, fifty-one out of eighty-six steckling beds showed less than 1 per cent of plants with yellows. Ten beds contained more than 10 per cent infected plants. The mean percentage in sixty beds which will probably be used for 1954 seed crops is 0·61 per cent compared with 0·22 per cent in 1952, 0·09 per cent in 1951 and 0·21 per cent in 1950. Beds in the isolation areas were generally satisfactory, twenty-one showing less than 1 per cent yellows, six between 1·8 and 2 per cent, and one bed in the Tweed Valley 5 per cent. The worst were in the Eastern Counties, where spraying did not adequately prevent infection. Of forty-nine beds sprayed, only eighteen had less than 1 per cent infected plants, sixteen had between 1 and 5 per cent and fifteen had over 5 per cent. In Bedfordshire sprayed beds were better, and beds sown under cover crops, and sprayed after the cover crop was cut, have very few infected plants. (Hull and Osborne.)

As soon as stecklings emerged at Dunholme this year, they were colonized by many alate *Myzus persicae*, and none of seven systemic insecticides used prevented yellows from developing. Early spraying probably gives poor results because little insecticide is absorbed by small seedlings, and extra seedlings emerge after the spraying. Soaking the seed in systemic insecticides before planting, or watering them on to the soil when the seedlings were beginning to emerge, prevented the seedlings from becoming colonized by aphids, but it also decreased the stand of seedlings.

Experiments to test the effect of spraying root crops with systemic insecticides on the incidence of yellows were continued. They showed that the effect of two sprayings varies greatly from year to year and from crop to crop, depending on the nature of the particular outbreak. When only a few plants are infected by aphids that bring virus into the crop, and most of the yellows results from secondary spread within the crop, then insecticides greatly decrease the incidence. In these conditions, however, the losses in yield from yellows are small, and although spraying may decrease incidence by factors of from 2 to 5, the treatment is unlikely to be an economic proposition. When infection occurs early and

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many plants in a crop are infected by incoming aphids, then all the plants on sprayed and unsprayed plots may become infected. In these conditions, spraying simply delays, by two to three weeks, the time when the crop becomes 100 per cent infected. However, as yield of sugar is greatly decreased by infections early in the life of plants, this delay in time of infection may be useful, and these are probably the conditions in which spraying gives the greatest return, despite its apparent lack of effect. (Gates.)

Systemic insecticides were sprayed on fodder-beet crops a few days before lifting to see whether they would kill aphids and so prevent them from infesting clamps. A field crop of fodder beet, variety Hunsballe X, was sprayed with 0·2 per cent parathion at the rate of 100 gal. per acre, on 11th November 1952, and lifted and clamped three days later, before the plants could become reinfested with winged aphids. In the following April no aphids, or any other arthropods common in clamps, such as spiders, gnats, and flies, were found in the clamp of sprayed fodder beet, whereas a control clamp of unsprayed beet was infested with aphids (*Myzus persicae* Sulz) and other insects. "Systox," parathion and "Pestox 14" were tested to find the concentration needed when spraying fodder beet in October to kill all aphids that feed on cut leaves. All three need to be applied at three times the concentrations normally used on sugar beet in the summer.

In addition to using insecticides to prevent aphids from being introduced into clamps, maleic hydrazide, a growth-regulating substance, was tested for its ability to check sprouting of stored roots, with the idea that this might decrease infestations. Mangolds were sprayed with 0·25 per cent maleic hydrazide in the field on 15th October 1952 and were clamped in the usual way, with unsprayed mangolds acting as a control. In the following April the sprouts on the sprayed plants were only half as big as those on the controls. In another experiment Klein E sugar beet was sprayed with 1 per cent maleic hydrazide on 5th November 1952, harvested on 21st November and stored in damp sand in a cellar. Sprayed and unsprayed plants both started to sprout immediately, but by February differences were apparent, for the sprouts on the sprayed plants were then 2 inches long, whereas those on the unsprayed were 4 inches. In July 1953, when the control shoots were 18 inches long, the sprouts of the sprayed plants were only 4 inches. (Cornford.)

Of various weeds tested, three were found susceptible to sugar-beet yellows. The leaves of infected *Senecio vulgaris* became yellow, thick and brittle. Passage through this host did not affect the type of symptoms produced in sugar beet by mild and virulent isolates. In one test with *Capsella bursa-pastoris*, infected plants were stunted, but in another they were indistinguishable from uninfected plants. Even when a virulent isolate was used, the virus recovered caused only mild symptoms in beet. *Stellaria media* showed no symptoms when infected, but sap from infected plants reacted strongly with virus antiserum. Isolates virulent to beet were recovered apparently unchanged by passage through this host. (Hull.)

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Mycology

Spore dispersal

The wind tunnel was moved to a specially designed wooden building, so that outdoor air can be used and plants kept alive in the tunnel for several days at a time. Using a modified version of the Hirst spore trap designed to put in the wind tunnel, the production of spores by plants kept under known wind conditions was studied and compared with the results obtained by trapping in the open.

Tests so far have been done mainly with wheat and barley plants, heavily infected with powdery mildew (*Erysiphe graminis*). At a constant wind speed of 2 m.p.h. spores were liberated with the same diurnal periodicity as found by Hirst when using the suction trap in the open. Spore liberation therefore appears to be independent of wind speed. Keeping the plants in constant light, or in constant darkness, for periods up to 72 hours did not change the diurnal periodicity, which is evidently not determined by light or darkness. Other variables, such as temperature and humidity, have yet to be examined. Potato shoots severely affected with potato blight did not produce spores in the wind tunnel, presumably because the relative humidity was too low. A small tunnel through which conditioned air can be passed, is being made to study the liberation of *Phytophthora infestans* spores. (Gregory; Hirst; Last; Stedman.)

The deposition of air-borne spores on plates charged to 4,000 volts (positive or negative in respect to earth) has been studied using electronic equipment designed and made by H. L. Nixon and H. L. Fisher. When *Lycopodium* spores are blown from a glass tube some are apparently negatively charged, but more appear to be charged positively, and others carry no charge. Vertical metal plates charged to 4,000 volts, arranged either parallel to or at right angles to the wind direction, catch up to ten times as many spores as they do when earthed. (Gregory and Stedman.)

Casella Ltd. are marketing a commercial model of the Hirst automatic spore trap, and this was calibrated against the "Cascade" Impactor, using both large (*Lycopodium*) and small Mushroom spores. (Hirst and Stedman.)

A portable hand-operated volumetric spore trap was designed for use where there is no power supply and the Hirst automatic trap cannot be worked. The apparatus was tested under a variety of conditions to find its advantages and limitations. It is particularly valuable for making many measurements of the spore content at short time intervals, and for studying how spore concentration varies at different distances from their place of liberation. (Gregory.)

The automatic spore trap was used to study the dispersal of ascospores and conidia of the apple scab fungus (*Venturia inaequalis*), the spore concentration in wheat stubble infected with *Ophiobolus graminis* and *Cercosporella herpotrichoides*, and in commercial mushroom-growing houses. (Gregory and Hirst.)

Potato blight

In the hope of improving disease forecasting, the correlation between weather and infections by *Phytophthora infestans* was again

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studied in four parts of the United Kingdom, where the weather was recorded, both in screens 4 feet above the ground and in potato crops. At Rothamsted conditions affecting the liberation of spores, and the conditions that allow them to infect, were further studied by measuring the concentration of *P. infestans* spores in the air and finding when potted potato plants, which were placed in the potato field each day, became infected. The progress of the disease on individual shoots was recorded to study in what way modifying the ecoclimate, by irrigation at different times of the day, or by preventing the deposition of dew, affected spread. Although the treatments were not started until blight had already occurred, increasing water increased infection in both foliage and tubers.

A continuously recording dew-balance was made that measures the amount of water deposited on a potato shoot and the length of time for which water deposits persist. This should allow the importance of water films in affecting potato blight to be tested adequately.

Potato blight in 1953 was recorded at Rothamsted on 23rd July, the earliest outbreak since records were first taken in 1940. The disease spread moderately fast until September, when dry weather stopped it. Experiments in which Majestic potato crops had two well-timed copper sprays and the haulm was killed with sulphuric acid, showed that these measures increased yield of tubers by only ½ ton per acre. A tractor sprayer with an eight-row boom passing through the crop three times reduced yield by about 7 cwt. per acre. Less than 1 per cent of tubers from sprayed or unsprayed plots had blight. During the dry weather in September, the weight of tubers decreased by about 1 ton per acre when the haulm died. Loss of water to the dying haulm or to the soil may be the cause, but unfortunately dry weight was not estimated. The decrease occurred earlier on unsprayed than on sprayed plots; had the experiment been harvested when only the haulm of the unsprayed plots was dead, spraying would have seemed to have increased yield by about 2 tons per acre.

Powdery mildew of cereals

Studies on the effect of nitrogenous fertilizers (N) on the incidence of mildew (*Erysiphe graminis*) on winter wheat grown in pots were finished. Applying N to plants of different ages affected the incidence differently. When applied before the flag leaf had emerged, the infection-index (number of pustules per 100 sq. cm. of leaf blade) increased to a maximum and then declined. Applied after the flag leaf had emerged, the infection-index increased steadily without reaching a peak, and the increased susceptibility was not associated with an increased relative leaf growth rate as when N was applied earlier. Plants given N in either April or May had at least three times as many pustules as those given N in January. The time when N was applied did not affect the date when perithecia appeared. After adding N to nitrogen-deficient plants, the mature leaves, which had previously resisted mildew, became susceptible.

A series of field experiments was started to test the effect of date of sowing on the incidence of mildew. Barley was sown on four dates from 28th February to 22nd April 1953. Pustules were

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first observed in mid-May. Subsequently the number of pustules per unit area increased rapidly, and the plants sown on 22nd April (fourth sowing date) were the most susceptible.

The spore content of the air within and above two mildewed cereal crops, (*a*) barley on the Garden Plots and (*b*) wheat on Broadbalk, was measured in June and July. Most spores occurred at the base of the crops, the concentration decreased rapidly near the top of the crop, and was always greater within the crop than in the air above.

The two most numerous types of spore are (*a*) *Cladosporium* and *Erysiphe* on dry days and (*b*) *Sporobolomyces* and *Tilletiopsis* on wet days. In Broadbalk wheat the concentration of spores varied greatly in different plots. *Erysiphe* conidia occurred at 10,000 per cubic metre of air on dry and wet days in the heavily fertilized Plot 8, but hardly occurred in Plot 3, which receives no manure. On wet days only, both *Sporobolomyces* and *Tilletiopsis* spores occurred at 200,000 per cubic metre of air at 10 cm. from the ground in Plot 8, whereas *Sporobolomyces* occurred in Plot 3 at only 22,000 and *Tilletiopsis* at 40 spores per cubic metre of air.

Isolation of *Sporobolomyces* sp. from leaves of field crops gave results comparable with those from spore trapping. Many more colonies were obtained on agar plates from leaves taken low in a crop than from higher leaves, and leaves from Plot 8 on Broadbalk gave many more than leaves from Plot 3. (Last.)

Cereal foot and root rots

Land which was infested by weeds and on which wheat was severely infected by eyespot (*Cercosporella herpotrichoides*) and take-all (*Ophiobolus graminis*) in 1949, was used to test the relative cleaning action of three years under different crops. Plots in which wheat (Squareheads Master) grown in 1953 was the first, second, third, and fifth consecutive crop of winter wheat or barley, gave respectively mean yields of 37, 28, 19 and 15½ cwt. per acre; these included 11, 20, 32 and 32 per cent tail corn; 16, 47, 82 and 63 per cent of the straws had eyespot and 0·3, 24, 34 and 45 per cent had take-all at harvest. Effects on weeds were equally spectacular; about 1,775 heads of wild oats occurred in 10 sq. yd. in the plot with the fifth consecutive wheat crop, whereas only two occurred in 10 sq. yd. in plots that had not carried cereals during the previous three years. Full records exist from this and another experiment to show how various rotations affected the incidence of fungus diseases (eyespot, take-all, sharp eyespot *Corticium* (*Rhizoctonia*) *solani*, brown footrot, *Fusarium* sp.), and insect pests (wheat bulb fly, Hessian fly and stem sawfly), the density of the crop, the prevalence of weeds, lodging and yields of grain and straw. (Glynne, Salt and Slope.)

A field experiment testing the effects of seed rate, rate and time of applying nitrogen, and spraying with sulphuric acid on two varieties of wheat was continued for a second year. The crop was the fourth wheat crop in five years and, in addition to eyespot, it developed take-all and became weedy; consequently yields were lower than before. Decreasing the seed rate from 3 to 1½ bushels per acre decreased take-all and increased yield by 3–5 cwt. per acre. Sulphate of ammonia applied at 0, 2 and 4 cwt. per acre

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increased the area of Squareheads Master lodged from 22 to 51 and 58 per cent respectively, decreased take-all and increased yield from 14 to 18 and 19 cwt. per acre. The variety Cappelle did not lodge; the fertilizer decreased take-all and increased yield from 18 to 22 and 24 cwt. per acre. The lower seed rate and a heavy dose of nitrogen combined to increase yield of Squareheads Master from 12 to 22 cwt. per acre, and of Cappelle from 14 to 25 cwt. per acre.

Four years' work testing the effects of applying nitrogen at different dates to wheat have again shown that tillering is important in determining the incidence of eyespot. In pots, nitrogen given between October and April increased tillering early enough to delay infection of the straws, and so decreased the severity of lesions at harvest; when given in May tillering was too late to prevent the principal straws becoming severely infected, although young tillers escaped infection. In the field the effect of nitrogen in delaying infection of the straws was counteracted by its effect in increasing the luxuriance of the crop, which favoured the spread of the fungus. Nitrogen applied in October produced more tillers and fewer severe lesions at harvest than applications in March, April or May, which produced more luxuriant crops. (Salt.)

Annual surveys show that eyespot is the most important of the foot and root rotting diseases on the four- and six-course rotation experiments at Rothamsted. In the four-course experiment an average of 45 per cent straws were infected at harvest in the sixteen years 1938–53, the incidence varying from 3 to 86 per cent in different years; an average of 29 per cent straws were infected in the same period in the six-course experiment ranging from 2 to 80 per cent in different years. Sharp eyespot occurred in most years, brown footrot and take-all occasionally, but none seems important.

Six wheat varieties grown in pots differed in their reaction to eyespot. Of two high-yielding varieties, Cappelle yielded as much grain when infected by eyespot as did the four lower-yielding varieties when uninfected. Each variety suffered most loss when sown thickly and inadequately fertilized with nitrogen. No relation was found between tillering capacity and loss from eyespot. (Glynne.)

Clubroot of crucifers

Last year we reported the existence of races of *Plasmodiophora brassicae*. This has been confirmed, and an isolate from Norway was found to resemble isolates from Agdell field. The variety of swede called Wilhelmsburger, bred for resistance to clubroot in Denmark, is very susceptible to the Norwegian isolate.

The life cycle of the organism was studied by infecting plants grown in water cultures. A wide range of stages, from root-hair infections to mature galls, was obtained for histological examination.

Experiments on spore germination were made easier by making them in phosphate buffer instead of a full nutrient solution. Omitting nitrates has greatly reduced bacterial contamination and made it possible to lengthen the experimental period up to sixteen days. Variations in the germination of different spore suspensions experienced in previous years can partly be explained by the fact

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that germination depends greatly on the age of the parent gall. Spores from old galls germinate more readily than those from young galls, possibly only because they are mature. Storing spore suspensions at 4–5° C. seems not to affect germination. Almost all stages of germinating spores have been seen, contrary to reports by other workers, flagella were seen only on zoospores which were almost completely liberated. (Macfarlane.)

Sugar-beet diseases

Diseases of seedlings caused by *Phoma betae* carried in the seed and by soil fungi were this year greatly decreased by Phygon dust (1 per cent); by soaking for 20 minutes in ethyl mercury phosphate solution (40 p.p.m. active material); and by Dow 9B dust (0·5 per cent). Phemox was less effective than the standard dressing, Agrosan. Dressing with a fungicide is most effective when the crop is sown early and the soil is cold, conditions in which many seedlings rot before they come above ground. (Gates.)

The introduction of mechanical harvesters for beet increases damage to roots and necessitates longer periods of storage. Work has therefore been started to find the extent of losses and their causes. Roots harvested from two fields differed little in sugar loss after storing until February in a cellar. Undertopped roots lost more sugar than overtopped ones. When sampled early in January roots stored fresh lost the same amount as dried roots, but by February the dried roots had rotted more. Bruising also increased loss and rotting. The mean loss of sugar was 7 per cent by early January and 10 per cent by early February. *Botrytis cinerea*, the main cause of rots, affected more roots from one field than from the other, was more severe on the dried roots, and on roots bruised to simulate the damage caused by mechanical harvesters, than on those harvested normally.

When beets were cut lengthwise and the freshly cut surfaces covered with *Botrytis* spores, the tissue under the crown to a depth of about ½ inch resisted infection. When this tissue was removed, as is done in " topping " the beet, the exposed surface was invaded when exposed to a concentrated suspension of *Botrytis* spores, but not when exposed to a dilute one. If the cut surface was exposed to the air for about a week, the surface cells became suberized and resisted attack. A wet cut surface also became a barrier to *Botrytis* germ tubes after only two days. (Hull and Cornford.)

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