# Report for 1952

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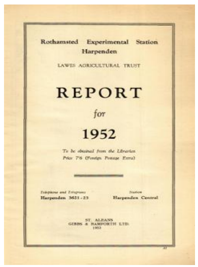
REPORT
for
1952

## Plant Pathology Department

### F. C. Bawden

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# PLANT PATHOLOGY DEPARTMENT

F. C. Bawden

During T. W. Tinsley's secondment to the West African Cacao Research Institute, G. D. Heathcote was appointed to work on virus diseases of cruciferous crops. F. M. Roberts, on secondment to the Clove Research Scheme, Zanzibar, identified *Cryptosporella eugeniae* sp. nov. as the cause of serious die-back in clove trees, and obtained much evidence suggesting that sudden death is caused by *Valsa eugeniae* sp. nov. B. M. Hamlyn worked in Holland for a month, exchanging posts with Miss G. Molinaar, from Wageningen. Professor H. J. Brodie, on leave from the University of Indiana, spent five months in the department.

As the guest of the New York Academy of Sciences, in January F. C. Bawden attended a conference at New York on the Nomenclature and Classification of Viruses and Rickettsia. R. Hull attended meetings of the International Institute of Sugar Beet Research at Brussels in February and at Bergen op Zoom in March and December; he and L. F. Gates attended a conference on sugar beet yellows arranged jointly by the German Ministry of Agriculture and the European Plant Protection Organization at Cologne in September.

B. M. Hamlyn was awarded the degree of M.Sc. of Reading University and J. W. Blencowe the degree of Ph.D. of London University.

## Viruses and Virus Diseases

### *Experiments with ultraviolet light*

Various effects of exposing viruses and leaves to ultraviolet light were described in last year's report. Some of these have been studied in greater detail and the action of ultraviolet has been used to study the movement and distribution of viruses in leaves. Much evidence was gained that only the epidermal cells are affected when leaves are irradiated; the effects of ultraviolet irradiation are temporary if the leaves are exposed to visible light within 1 to 3 hours after they have been irradiated, but, if not, the epidermis is permanently injured. Virus present in the epidermal cells can be inactivated and appears to remain inactive whether or not the leaves are immediately exposed to visible light.

The production of lesions in inoculated leaves can be prevented by irradiation with ultraviolet light; the maximum length of time after inoculation that irradiation prevents lesion formation varies with different viruses and host plants; irradiating French bean leaves 8 to 12 hours after they had been inoculated with a tobacco necrosis virus usually had no effect on numbers of lesions, whereas lesion formation in *Nicotiana glutinosa* inoculated with tobacco mosaic virus was usually prevented by irradiating 18 to 24 hours after inoculation. This difference is interpreted as showing that different viruses take different times to multiply in and move from the epidermal cells. Infection was equally prevented by irradiation whether or not the inoculum contained some substance such as "Celite," which greatly increases the number of lesions produced by a virus preparation. The suggestion that these substances may facilitate infection because they introduce virus particles into cells other than the epidermis, therefore, seems unfounded (Bawden).

Many aphid-transmitted viruses are optimally transmitted when aphids, which have previously been prevented from feeding, are fed for only a minute or so on infected leaves before they are transferred to healthy plants. Evidence was obtained that these viruses, of which typical examples are henbane mosaic, cabbage black ringspot, potato Y, cucumber mosaic and sugar beet mosaic, may occur predominantly in the epidermal cells of systemically infected plants. When both the upper and lower surfaces of leaves infected with cabbage black ringspot or henbane mosaic viruses were irradiated with ultraviolet, the sap expressed from the leaves was only about one-fifth as infectious as sap from comparable unirradiated leaves, although the epidermal cells amount to only about one-fifth of the total volume of the leaves. Using the conditions of a short feeding time that normally give the largest number of transmissions, aphids rarely transmitted these viruses from leaves that had been irradiated. When left to feed on infected leaves for 24 hours before being transferred to healthy plants, only a few aphids gave transmissions whether they had been feeding on irradiated or unirradiated leaves, but they gave as many from the one as from the other. Thus it seems that aphids can acquire this type of virus from deep-seated cells, but do so with much greater difficulty than from the epidermis.

Very different results were obtained with sugar beet yellows virus; aphids that have fed on infected leaves for only a minute do not transmit this virus, the transmission of which becomes increasingly probable the longer the time that aphids feed on infected plants before being transferred to healthy ones. This virus was transmitted about as frequently from irradiated as from unirradiated leaves, a result agreeing with other evidence suggesting that aphids probably acquire this virus from the phloem (Bawden, Hamlyn and Watson).

When tobacco mosaic virus is irradiated with ultraviolet light, its resistance to denaturation by heat can be changed. This change in properties is not directly correlated with the changes that lead to loss of infectivity, for the two properties are not affected simultaneously, and much more intense radiation is needed to affect the rate of heat denaturation than to destroy infectivity. The rate of denaturation by heat can be increased three times by prolonged exposure to ultraviolet radiation. Experiments with a *Rhizobium* bacteriophage showed that virus particles which still retain infectivity after preparations have been exposed to ultraviolet, are less stable and lose their infectivity sooner than do comparable but unirradiated particles; a similar phenomenon was also detected with trypsin, but not with the three plant viruses (tobacco mosaic, tobacco necrosis and tomato bushy stunt) tested. (Kleczkowski).

*Effects of environment on virus multiplication*

Commoner and others, working in the United States, found that the multiplication of tobacco mosaic virus could be inhibited by thiouracil and that its inhibiting effect can be counteracted by uracil. In their work, pieces of inoculated leaf were floated on nutrient solutions containing the substances and were continuously illuminated. Using comparable conditions, we have confirmed their results, but we have also found that the extent to which thiouracil inhibits virus production depends greatly on the physiological condition of the leaves. More virus is formed in cut leaves if they are floated on solutions of sugar and phosphate than if they are floated on water; more is also formed if the leaves are illuminated than if they are kept dark, particularly if they are floated on water. Oddly enough, thiouracil has the greatest effect in decreasing virus production in conditions where otherwise most virus would be produced. For instance, the sap expressed from leaves 6 days after inoculation with tobacco mosaic virus usually gives a precipitin titre with virus antisera of about 1/256, if the leaves have been illuminated and floated on a solution containing sugar and phosphate; in the presence of 0·01 per cent thiouracil, the titre falls to about 1/4. Comparable leaves floated on water in the dark, give a titre of about 1/64, and this falls only to 1/32 in the presence of thiouracil.

When using viruses and hosts that react with necrotic local lesions, thiouracil resembles trichothecin in that solutions sprayed over leaves within a day of inoculation prevent the production of lesions. Its action, however, is not restricted to the early processes of infection, for the multiplication of tobacco mosaic virus in tobacco leaves can be arrested even after it has been proceeding for 3 or 4 days. The virus already formed seems to be unaffected, but such leaves develop necrotic lesions, something which neither the virus nor thiouracil causes alone. (Bawden and Kassanis.)

Last year we reported that plants inoculated with tomato bushy stunt and cucumber mosaic viruses failed to show symptoms if kept at 37°C for a day or more immediately after inoculation. This suggested that diseased plants might perhaps be freed from these viruses if maintained for long periods at high temperatures. Experiments to test this were made with systemically infected *Datura stramonium* plants, which were showing severe symptoms when they were placed in a glass chamber maintained continuously at 37°C. The plants produced many new shoots, all of which looked healthy and from which no virus could be obtained by inoculation to healthy test plants. Cuttings struck from these shoots, taken after 4 to 5 weeks at 37°C, mostly grew into healthy plants in which no virus could be detected, although a few developed symptoms and from these virus was readily isolated. When removed from the glass chamber after 5 weeks, tests failed to reveal any virus in the parent plants, but after 3 to 4 weeks under ordinary glasshouse conditions, those originally infected with tomato bushy stunt virus again developed symptoms, and virus was then also readily recovered from them. Obviously the virus content of the plants was much decreased by the high temperature and the new shoots produced were mostly virus-free, but even 5 weeks was insufficient to free the whole of the original plants. In experiments with carnation plants systemically infected with carnation ringspot virus (a prevalent virus that in some ways resembles the tobacco necrosis viruses), healthy plants were also produced from cuttings taken from new shoots produced while the parent plants were maintained at 37°C. (Kassanis).

*Electron microscopy*

In the hope of ultimately obtaining direct evidence about the mechanism of virus multiplication and of the sites where it occurs, most of the year has been spent developing techniques for cutting and examining thin sections of leaves. An old Minôt-type microtome has been adapted to give serial sections by direct mechanical advance down to $0{\cdot}1\mu$, cutting with a glass fracture-edge.

The electron microscope has been fitted with a special objective pole-piece which allows the aperture to be adjusted both along and across the optic axis. To get the full benefit from the new lens, the whole of the power supply chassis of the microscope has been moved away from the microscope column, because alternating fields from the power transformers disturbed the image.

After some preliminary attempts with wax embedding media we adopted the methacrylate techniques of Newman, Borysko and Swerdlow (Science, **110**, 66 (1949)), using the harder isobutyl methacrylate instead of n-butyl methacrylate. This hard material is "plasticized" with cresyl phosphate to give a block of the desired hardness. The properties can be varied from a soft rubber-like material to a hard brittle glassy substance by altering the amount of plasticizer. Instead of 2-4 dichlorbenzoyl peroxide, which is heat-activated, we catalyse the polymerization of the methacrylate with phenylbenzoyl carbinol, which is light-activated. This allows all stages from fresh material to finished block without raising the temperature above 25°C.

The technique is now well advanced, and clear pictures of tobacco mosiac virus particles in cells of systemically infected plants are being obtained.

Less work has been done with clays than in recent years, but a start was made on methods of mounting which avoid artefacts caused by drying. This is essential if any studies of particle aggregation are to be made, and a simple method would also be useful for biological particles. Freeze-drying clay suspensions on to electron microscope grids has given promising results. (Nixon and Fisher).

*Aphid-feeding measured by radioactive indicator*

Previously the amount of material imbibed by aphids from leaves was measured by feeding them on plants growing in water-culture solution containing $P^{32}$. The rates of imbition were about $10\mu g$ per hour for the first hour of feeding, $40\mu g$ per hour for the next four hours, and $20\mu g$ per hour for the next nineteen. This suggested that aphids obtain little from the epidermis and mesophyll, and feed extensively only from the phloem. However, the results were not conclusive because, in plants obtaining $P^{32}$ through their roots, the indicator might occur predominantly in the vascular system. So as to ensure that there would be activity in superficial cells, the experiments were repeated using leaves that had been floated in culture solutions containing $P^{32}$, a technique previously found to give high activity. The aphids still acquired little activity during short feeding periods, and both sets of data suggest that aphids acquire food in quantity only when their stylets are in phloem cells (Nixon and Watson).

*Sugar beet virus diseases*

Six viruses or strains that cause yellowing of sugar beet were described in detail in the Report for 1951. Their serological behaviour, transmission by aphids and the diseases they cause have been further studied, but their relations one with another still remain largely undetermined. The only two with which positive serological reactions have been obtained are the stock culture of sugar beet yellows (SBY) and a more virulent strain of it (SBYN) that causes more obvious necrosis on infected leaves. No antigenic differences were found between these two, and antisera prepared against either were completely adsorbed by the other. Sap from plants infected with SBYN gave higher precipitin titres; that this strain occurs at a greater concentration was also suggested by electron micrographs of sap, in which filamentous particles were seen more frequently than in sap from plants infected with SBY. SBYN was also more readily transmitted by aphids (Blencowe and Watson).

With all six isolates, fewer transmissions were obtained when test plants were colonized with many aphids than would be expected from the number obtained with one aphid. SBY and SBYN caused more severe leaf symptoms and reduced weight of tops more in plants colonized with many infective aphids than in plants colonized with few. Plants with mild symptoms were frequently obtained when SBY was transmitted by colonizing test plants with few aphids; this happened less frequently with SBYN. Virus transmitted from such plants gives many plants with mild symptoms, but always gives some symptoms comparable with those typically produced by the parent type. Sap from these mildly affected plants, unlike that from those infected with viruses obtained from Eire and the United States that cause mild yellowing, always precipitated with antiserum prepared against SBY.

Other workers have claimed that sugar beet yellows virus persists in aphids for as long as 15 days after they cease feeding on infected plants. We have not confirmed this; the ability of aphids to infect with SBY and SBYN falls considerably within a day of leaving infected plants and no infections occur after 72 hours, although one of the viruses causing a mild yellowing persisted in the vector for 5 days (Watson).

Experiments to test the effects of varying dates of sowing and singling sugar beet were again made at Dunholme, Sprowston and Rothamsted; the treatments comprised all combinations of three dates of sowing (March, April and May), and three times of singling (early, normal and late).

Many aphids appeared on the plants during July; they were at first more numerous on the early sown beet, but the largest populations ultimately developed on the last sown. *Aphis fabae* was numerous at all centres; *Myzus persicae* was numerous at Dunholme and Sprowston, but rare on the beet at Rothamsted, although it was plentiful on other crops nearby.

Symptoms of yellows first showed on a few plants by early July after singling was finished, so varying singling date, as was to be expected, did not affect the incidence of yellows as it has in some other seasons. The first infected plants were seen among the early-sown beet, but spread was more rapid in the later-sown beet, which had larger populations of aphids. At Dunholme and Sprowston, however, nearly all the plants of all ages were infected by autumn. At Rothamsted only a small proportion of the plants was infected. The largest yields were obtained this year from beet which had been sown and singled early (Blencowe).

Samples of all stecklings used for sugar-beet seed crops in Great Britain were planted at Dunholme. Counts in June 1952 showed that the 131 samples had a mean value of 0·7 per cent plants with yellows. Forty-five samples from isolated districts had a mean of 0·7 per cent plants with yellows, and a range of 0–5·8 per cent. Forty sprayed beds in Eastern England had a mean of 1·8 per cent, and a range of 0–27 per cent. Twelve beds grown under cover crops had a mean of 0·3 per cent and a range from 0–2·5 per cent, and thirty-four beds which were sprayed and under cover crops had a mean of 0·1 per cent infected plants, and a range from –1·5 per cent.

Steckling-bed inspections were again organized in the autumn of 1952. Out of 110 beds, 101 showed less than 1 per cent of the plants with yellows. Five of those with more than 1 per cent were beds that should have had cover crops, but these had failed, so virtually they were early-sown open beds. The other four were sown very early and spraying had not given adequate control.

Stecklings sown on three dates were thinned to three different spacings to give roots of varying size, and in the autumn they were kept in the root store (warm), in a shed (cool) or outwintered in the ground. When planted out in the spring, over 80 per cent of the roots grew, except those from the late sowing, of which only 18 per cent kept in the root cellar and 28 per cent kept in the shed grew. Juice from these roots had a refractometer reading of 3–6 per cent sucrose, the same as from the middle sowing, of which 80 per cent grew. All other samples had refractometer readings above 6 per cent sucrose. Thus the close relationship between refractometer reading and plant establishment found earlier did not recur this year. The very favourable soil conditions, during and after transplanting this year, probably explain the better establishment with plants having low sugar contents. Although the different treatments were reflected in the size of the plants at first, the small plants grew more rapidly and by the end of June there were no differences in the average weight of the roots or overground parts of individual plants from any of the treatments (Cattrall, Hull and Osborne).

Experiments with systemic insecticides have been continued. Early spraying (August 31st and September 10th) had the greatest effect in reducing the incidence of yellows in steckling beds. October and November sprayings had almost no effect, as the aphid infestation declined during September. Systox was as effective as a mixture of Pestox III and XIV.

Three treatments combined factorially were tested for their effect on the incidence of yellows in the root crop: spraying with systemic insecticides compared with no spray; high and low plant populations; and plots infested artificially at the centre with alate compared with apterous *M. persicae*. The development of plants with yellows showed that many infective aphids entered the crop while the plants were still very small. Three sprayings in June and July reduced the incidence of yellows by 50 per cent at the end of August and 30 per cent in mid-October. Plant population had only a small effect this year, the number of infected plants per unit area was similar on plots of high and low population. No effect of introducing alate or apterous *M. persicae* was noticed, because of the influx of aphids from other sources.

The effects of early spraying (1st week July), late spraying (last week of July), and spraying on both occasions, were investigated on plots of about 1 acre in six fields in Lincolnshire and Norfolk. At Swineshead all plots were nearly 100 per cent infected by the end of August; on one field, however, the sprayed plots were noticeably less yellow and when lifted showed a good increase in yield. At Wisbech yellows was slight and, although sprayed plots had fewer infected plants, no effect on yield was detected. At Stradsett yellows was more prevalent and was partly controlled by spraying (Gates).

Glasshouse experiments showed that *Rhopalosiphoninus staphyleae* transmitted SBYN about half as frequently as did *M. persicae* ; *R. staphyleae* transmitted sugar beet mosiac virus to one plant in fifteen but did not transmit yellow net virus to any fifteen plants (Cornford).

The effects of a virulent and a mild strain of yellows were compared in a breeder's line (Rose 7582) and a commercial variety (Sharpe's E).

The virulent strain produced symptoms earlier on more plants of the line than on Sharpe's E, though eventually the percentage of plants infected was the same. Some plants of Sharpe's E were very slow to show symptoms, and then symptoms were mild for a while; others quickly showed very severe symptoms and were severely stunted. The symptoms on the line were more uniform and less severe than on the worst affected Sharpe's E plants.

The mild strain produced symptoms more slowly in the line than on Sharpe's E. It caused much more intense yellowing on Sharpe's E than on the line, and this was reflected in the effect on sugar yield. The mean sugar yield for the nominally healthy plots (which became infected later in the season) was 55·4 cwt. per acre of sugar, for the plots infected with mild yellows 49·8 cwt. per acre and with necrotic yellows 42·3 cwt. per acre. Most of the loss was from a decrease in size of roots, and the mean effect of infection on sugar content was only 0·4 per cent.

Thirty-two single-plant progenies, raised in isolation plots along with sister plants, were infected with a mild strain of yellows, the necrotic strain, yellow net, beet mosaic and cucumber mosaic virus. The reaction of individual plants in each progeny to the necrotic strain varied considerably, indicating a lack of genotypic uniformity with this degree of inbreeding. However, there were obvious average differences between the progenies. Lines that gave the mildest symptoms usually also gave most symptomless plants. More consistent behaviour within lines was obtained with seed from self-pollinated plants.



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The single-plant progenies all reacted similarly to mild yellows, except that some showed symptoms more slowly, and to beet mosaic virus. By contrast, the progenies differed strikingly in their reaction to cucumber mosaic virus. All plants of some progenies were crippled whereas others produced only small, ephemeral local lesions. Large differences also occurred with yellow net virus. Some progenies gave brilliant systemic symptoms on most plants, whereas others gave only localized symptoms or none (Hull).

*Virus diseases of cruciferous crops*

Of two isolates of cauliflower mosaic virus (ClMV), the one that caused the more severe symptoms was also more readily transmitted. Both isolates were more readily transmitted to and from turnip plants than to and from cauliflower plants. Cabbage black ringspot virus (CBRV) was transmitted more readily by aphids from the lower leaves of infected turnip plants than from upper leaves: this was true whether plants had been systemically infected for 2 or 12 weeks (Hamlyn).

Of twelve species of aphids tested, *Brachycaudus helichrysi*, *Hyalopterus arundinis*, *Macrosiphoniella sanborni* and *Coloradoa rufomaculata* failed to transmit either ClMV or CBRV: *Brevicoryne brassicae*, *Myzus persicae*, *Myzus ascolonicus*, *Aulacorthum circumflexum*, *Macrosiphum euphorbiae*, *Megoura viciae* and *Sappaphis radicicola* transmitted both, and *Hyperomyzus lactucae* transmitted ClMV but not CBRV. Despite the many species that can transmit, the viruses seem to spread in the field only when either *Myzus persicae* or *Brevicoryne brassicae* are active.

In July and August there were unusually large migrations of *B. brassicae* across the middle of England, where both ClMV and CBRV spread extensively, whereas both were much less prevalent in the south and north. Plants were exposed during a migration on 26th July and, when flight had ceased, they carried populations of up to 1,200 aphids per plant. Unlike previous years, in 1952 CBRV was as prevalent as ClMV in some districts. The two viruses are differently distributed in infected plants. Both viruses invade the young leaves of freshly infected seedlings, but whereas ClMV remains equally distributed through all the plant, CBRV occurs predominantly in the older leaves, and the middle and upper leaves contain little or none. Migrating aphids mainly alight on middle and upper leaves; ClMV is much more readily transmitted than CBRV from these leaves, which may well explain the fact that ClMV is usually the more prevalent virus, despite the greater host range of CBRV, and the fact that from leaves showing pronounced symptoms aphids transmit it more frequently than they transmit ClMV. The greater ability of ClMV to invade and multiply in young tissues was further shown by its recovery from the curd and opened flowers of cauliflower and from the heart leaves of cabbage, whereas CBRV could not be transmitted from these parts of plants whose outer leaves had a high virus content and showed many ringspot lesions.

In two experiments seed-beds of cauliflower were sprayed at intervals of 7-10 days with Systox, Pestox 3, Parathion, Toxaphene, D.D.T., Pyrethrins and Pyrolan, but none significantly reduced the incidence of either virus. Increasing the density of plant population by increasing the seeding rate did, as also did barriers of various types surrounding the beds. The barriers also reduced the number of infected plants per area of land and promise to be of practical value. Strips of barley and wheat were more effective than strips of mustard and kale or than simple physical barriers such as hop-lewing and sisal-kraft. These tests were with small seed-beds, and further experiments are needed to find what size bed can be protected from incoming aphids by such barriers (Broadbent and Heathcote).

Various yellow aphid traps were operated to test their relative efficiency. Moericke's 'Water-Bath' trap caught twice as many aphids as did a flat sticky trap of equal area, possibly because aphids crawl off the flat sticky flap. Cylindrical sticky traps of half and quarter the diameter of the standard size (5″) all caught approximately the same numbers.

The small sticky traps were more difficult to handle than the standard size, and the water trap required more frequent attention, but yielded undamaged specimens. The different traps seem to select different aphids; e.g. *Anoecia corni* formed only 1·3 per cent of total caught on flat traps, but 19·2 per cent on the vertical traps (Heathcote).

*Potato virus diseases*

Records made in 1952 on plants grown from tubers from the 1951 experiments showed that there was little spread of potato virus diseases in either the ware- or seed-growing areas of England and Wales. However, there was enough in experiments at Rothamsted to show that spraying with some insecticides was beneficial, particularly in preventing the spread of leaf roll. The experiment was made with Stock Seed Majestic potatoes and tubers infected separately with virus Y and leaf roll virus were introduced to give 0·65 per cent of the crop infected with each. The plants were sprayed altogether 7 times at intervals of 10-14 days. The table shows the percentage of infected plants in bulk samples of tubers taken at harvest and in selected samples taken from the five plants on each side of the introduced infectors. It would seem that most of the leaf roll in sprayed plots was brought in from outside and did not spread from the sources within the crop.

| | % plants infected in bulk plot sample | | % plants infected in 5 plants on each side of infectors | |
|---|---|---|---|---|
| | LR | Y | LR | Y |
| Unsprayed .. .. .. | 5·4 | 8·2 | 23·9 | 50·8 |
| D.D.T. .. .. .. .. | 1·1* | 3·6* | 0* | 14·6* |
| Parathion .. .. .. | 1·2* | 5·3 | 0* | 15·6* |
| Isopestox .. .. .. | 0·8* | 7·7 | 0* | 26·5* |
| Dieldrin .. .. .. .. | 2·6* | 6·1 | 10·0* | 31·3 |
| Toxaphene .. .. .. | 2·8* | 6·0 | 5·1* | 30·5* |

* significant decrease

(For details of formulation and application see report of Insecticides Dept.)

In 1952, in co-operation with the National Agricultural Advisory Service, and firms of insecticide manufacturers, commercial crops were sprayed with insecticides on two farms in Essex, to see for how long a stock of potatoes can be maintained healthy in districts where virus diseases normally cause rapid degeneration (Broadbent).

## Mycology

### *Spore dispersal and trapping*

The wind tunnel was used to study the deposition of spores on sticky traps, including vertical and horizontal microscope slides, cylinders and Petri dishes such as are generally used in aerobiological surveys. Deposition occurs because of several effects acting singly or together. Gravity plays only a minor part. The catch is increased as the wind speed increases from 0·5 to 9·5 metres per second, but varies with both wind speed and the angle of the trap to the wind. The concentration of spores in the air is difficult to estimate from deposits on plane surface traps, because horizontal traps under-record at medium wind speeds and the catches on vertical traps vary greatly with changes in wind speed. Reliable data on spore concentration can be obtained only with power-operated suction traps (Gregory and Stedman).

Using suction traps, either the Cascade Impactor or Hirst's automatically recording trap, the whole range of spores in the air can be caught. These catches show that basidiospores, previously unrecognized as a major component of the "spora" (the spore population of the atmosphere) in both outdoor and indoor air can at times exceed all other components of the air spora. The concentration of coloured and colourless basidiospores, presumably from agarics and polypores, is maintained at over 1,000 per cubic metre for several weeks in late summer. Their diurnal fluctuation is peculiar, for most occur in the early hours of the morning. During some nights, very large numbers of minute basidiospores, thought to belong to the mirror yeasts, *Sporobolomyces*, have been recorded.

The improved trapping methods have also been used to estimate the concentration of spores of the dry-rot fungus, *Merulius lacrymans*, in affected buildings, and again high concentrations of basidiospores have been recorded (Gregory and Hirst).

Four non-suction traps (Vertical Cylinder, Horizontal Slide, Petri-dish and Funnel) were compared in the field with Hirst's suction trap. The results showed:

1. The absolute number of spores per cubic metre of air over a period of a day cannot be calculated from catches in a non-suction spore trap.
2. On days with the same mean wind speed, the efficiencies of both the horizontal slide and vertical cylinder varied by a factor of ten.
3. A smaller range of spore types was caught on the non-suction traps than on the suction trap.
4. The number of spores of any type caught per sq. cm. by the suction trap was more than 100 times as many as on the horizontal slide. The vertical cylinder caught relatively more pollens and relatively fewer spores of smut fungi, *Cladosporium* and *Alternaria*, than the suction trap.
5. The relative catches of spores in two funnels, one of which was shielded from rain, showed that many spores were carried down by rain (Gregory, Hirst and Last).

*Potato blight*

Potato blight developed late and slowly at Rothamsted in 1952; conditions were not well suited for experiments in which potato plants in pots were exposed in crops to find what conditions influence sporulation, dissemination, infection and incubation period of *Phytophthora infestans*.

To give information on the relation between conditions in potato crops and those under which normal meteorological records are made, continuously recording wet and dry bulb thermometers of various types have been operated at a range of heights both in and above the potato crop. In hot dry weather, particularly before the leaves are fully developed, mid-day temperatures are considerably higher, and relative humidity lower, at crop level than in a Stevenson screen at a height of 4 ft. At night, temperatures are similar but humidity is higher in the crop. When a full leaf canopy is established, and particularly when the soil is wet, temperatures are similar in crop and screen, but relative humidity is higher in the crop throughout the 24 hours. These, and other measurements from a balance which continuously records the weight of a potato shoot, have been used to study the conditions and times of formation and persistence of water droplets on potato leaf surfaces.

Meteorological data, including continuous records of temperature and humidity from several stations, were used to compare the applicability of various forecasting methods, and to test possible improvements. " Beaumont periods " measured at crop level were more frequently correlated with blight outbreaks than when measured in Stevenson screens. The feasibility of determining " Beaumont periods " at crop level, from daily recordings of wet and dry bulb maximum thermometers and a minimum thermometer, was tested at four stations. It seemed a possible method of reducing the cost and difficulty of maintaining a large network of forecasting stations, but too many inaccuracies were found to encourage further investigation or adoption of the method (Hirst).

*Clubroot of cruciferous plants*

The effect of various cropping treatments on the persistence of *Plasmodiophora brassicae* in soil was studied by box and pot experiments, using the production of clubs to measure treatment effects. Growing cabbage, ryegrass and poppies in infested soil reduced subsequent infection of susceptible plants. In one experiment the proportion of infected test plants was reduced from 57 per cent after fallow, to 28 per cent after cabbage and 19 per cent after ryegrass, but it has not been possible always to repeat this result.

While testing soil samples from Agdell Field, it was suspected that the *P. brassicae* there might differ in its host range from the organism which has been maintained for some years on cabbage in the greenhouse. A preliminary trial showed that turnip, swede and cabbage were heavily infected in Agdell soil, whereas only cabbage developed severe clubroot with inoculum from the stock cabbage plants. A more extensive experiment using fresh " isolates " of *P. brassicae* from both sources showed clear differences between them, as follows :—

*% diseased plants*

| *Inoculum* | Cabbage | Turnip | *Host* Swede | Radish | Cress (*Lepidium sativum*) |
|---|---|---|---|---|---|
| Cabbage—stock material | 100 | 1 | 0 | 21 | 12 |
| Swede—Agdell soil | 100 | 68 | 100 | 0 | 88 |

Much attention was given to studying spore germination. Two methods of estimating germination have been used with spore suspensions: (1) removing small samples from the suspension, a procedure which is difficult because the spores clump; and (2) using small drops of suspension on slides, which can be examined directly. The second is better. Germination is influenced by the moist chamber in which the drops sit, the slide surface and the spore suspension. The last is the most important factor, and the proportion of spores that germinates varies from one suspension to another by five or more times. The stage of development of the gall from which the spores are extracted seems largely to determine the germinability of spores. Suspensions from old galls may contain up to 25 per cent empty spores, suggesting that spores can germinate as soon as the host cell dies. Spores have been suspended in water at 5°C for several months without apparent deterioration. Drying will kill about half the spores.

Methods for studying germination are now thought to be reliable enough to start an investigation of the way the rhizosphere affects germination (Macfarlane).

### *Cereal foot and root rots*

An experiment which tested the effects of two years under different crops in freeing land from eyespot (*Cercosporella herpotrichoides*), take-all (*Ophiobolus graminis*) and weeds, showed that winter wheat following wheat or barley had 60 per cent of the plants infected by eyespot, and yielded 24·3 cwt. per acre; in April, 16 per cent of the plants had take-all, but sulphate of ammonia reduced it to 2 per cent at harvest. Where wheat followed oats or spring-sown ryegrass after a non-susceptible crop, only 14 per cent of the plants were affected by eyespot, there was no take-all and the yield was 35·7 cwt. grain per acre.

A similar experiment begun a year later gave similar results. Wheat following wheat had 77 per cent straws infected by eyespot and 17 per cent of the plants had take-all at harvest. One year free from wheat and barley reduced eyespot incidence to 38 per cent and take-all to 2 per cent. Two years free from wheat and barley but with autumn-sown ryegrass in one or both years, reduced eyespot to 24 per cent and take-all to 1 per cent. With potatoes instead of ryegrass, eyespot was reduced to 1 per cent and there was no take-all. Wild oats were abundant in continuous wheat, less abundant but still common after one year, and scarce after two years, under other crops. Striking differences in the appearance of the wheat after different rotations suggest that yields, which are not yet known, were again correlated with the incidence of disease (Glynne and Salt).

Two varieties of winter wheat (Bersée and Squarehead's Master) were grown on eyespot-infested land, to test the effects of varying seed rate, rate and time of application of sulphate of ammonia, and spraying with sulphuric acid in March. Decreasing the seed rate from 3 to 1½ bushels per acre decreased lodging and increased the yield of grain by 4 and 5 cwt. per acre in unsprayed and by 1 and 3 cwt. per acre in sprayed plots of Squarehead's Master and Bersée respectively. Spraying with sulphuric acid reduced the area of Squarehead's Master lodged at harvest from 95 to 36 per cent, eyespot from 88 to 39 per cent, and increased yield from 22 to 32 cwt. per acre. In Bersée, spraying reduced lodging from 54 to 1 per cent, eyespot from 84 to 34 per cent and increased yield from 33 to 44 cwt. per acre.

Responses to nitrogen were controlled by the earliness and the extent of lodging. This depended on the rate and date at which sulphate of ammonia was applied, for this determined the weight of straw but had little effect on the incidence of eyespot. Nitrogen applied in March caused most lodging in both varieties. In Squarehead's Master it failed to increase yield, whereas applied in October, April or May it caused less lodging and increased yield by 2 to 3 cwt. per acre. In Bersée all applications of nitrogen increased yield; March application, with 70 per cent of the area lodged, increased it from 29 to 33 cwt. per acre; October application, with only 47 per cent of the area lodged, yielded 38 cwt. per acre; April and May applications each yielded 32 cwt. per acre. When eyespot and lodgings were controlled by spraying yield was increased from 37 to 46 cwt. per acre by nitrogen applied in October, March and April, and to 43 cwt. per acre when applied in May. A yield of 49 cwt. per acre, one of the highest yields of wheat recorded at Rothamsted, was obtained by sowing Bersée at 1½ bushels per acre, spraying with acid and applying 4 cwt. per acre sulphate of ammonia in March (Salt).

*Gibellina cerealis*, a fungus which causes an interesting disease of wheat, hitherto recorded occasionally in Italy, once in France and once in Hungary, has been found in 17 of the last 18 years on the alternate wheat and fallow experiment on Hoos field, but nowhere else in Britain. It is as common after three as after one year's fallow; it severely affects individual plants, but attacks so few that it is unlikely to have affected crop yields, even in 1952 when it was commoner than in any other year. It infects barley, rye, Italian ryegrass and perennial ryegrass (Glynne).

### *Cereal Mildews*

Observations on field crops showed that spring-sown cereals were much more heavily attacked by mildew than winter-sown cereals, and that the later the spring crops were sown, the more severely they suffered.

Experiments in glasshouses showed that the wheat variety Red Standard was more susceptible to infection by *Erysiphe graminis* at 14-20°C than at 7°C. After three days at 20°C before being inoculated, it was equally susceptible whether kept at 7°C or 20°C after inoculation. At 14°C pustules produced conidia more than ten times as rapidly as at 7°C.

The extent to which plants were affected was direcly correlated with their growth rate. Increasing the average growth rate was soon followed by an increase in the amount of infected leaf. When plants of different sizes were given equal amounts of nitrogen, the initially smaller plants became more heavily infected than the larger plants (Last).

*Sugar beet diseases*

Field experiments with seed treated with various fungicides showed that Panogen and ethyl mercury phosphate gave significantly better emergence than Agrosan. Granosan M and T.M.T.D. 1·33 per cent gave slightly better results than Agrosan, but differences were not statistically significant. Best emergence (56·0 seedlings per gram seed) was with seed dipped for 20 minutes in ethyl mercury phosphate solution at a strength of 30 parts per million; relative results were 49·9 for Agrosan and 37·4 for untreated seed (Gates).

Experiments were continued to study how wetting the cotyledons and leaves of sugar-beet seedlings before inoculation affects their susceptibility to infection by downy mildew (*Peronospora schachtii*) conidia. Some seedlings were wetted continuously for two days in the open, a treatment that retarded their growth rate and significantly increased the proportion that resisted attack by the fungus. This confirmed the result of an experiment made in August 1951. Similar experiments with potato blight fungus showed that wetting potato leaves also retarded their growth rate, but it increased their susceptibility to this fungus (Cornford).