ROTHAMSTED RESEARCH

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Introduction

The drier and warmer autumn than usual in 1980 enabled target dates for cereal experiments to be achieved but also encouraged cereal aphids and the consequent autumn infection by barley yellow dwarf virus. The Infectivity Index, developed in an attempt to improve forecasting of spray need, accurately predicted a high level of infection and responses to autumn aphicide in cereal experiments were substantial, more so at Woburn where infection was more severe. The situation may have been worsened by the mild winter that allowed aphids to survive and possibly multiply. Wet conditions in late winter and spring encouraged epidemic development of chocolate spot in winter beans with disastrous effects except on those plots that had received a seed treatment of benlate

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plus thiram. In addition these same conditions delayed spring planting with the result that some potato experiments had to be planted in very wet, cold soils that encouraged development of blackleg.

Cool, cloudy weather in June and July, followed by a wet pre-harvest spell contributed to the development of cereal foliage diseases to levels not reached for many years, in in common with most parts of the country. As a consequence, responses to fungicide applications were commensurately large, as for example on the multifactorial wheat experiment at Rothamsted where fungicides gave a mean yield increase of 1·67 t ha^{-1}, mainly by controlling *Septoria*. Potato blight was also encouraged by these conditions and became widespread by the end of August on unsprayed crops, though generally well controlled by fungicides. Powdery scab was again common, including the so-called severe 'canker' form, especially on some stocks of Pentland Crown. The recent general increase in levels of this disease is of some concern because apart from causing direct damage, the causal fungus *Spongospora subterranea* is also the vector of virus causing spraing and mop top, to which some widely grown varieties are susceptible.

This year's cool wet autumn resulted in few cereal aphids being caught in Rothamsted suction traps and a new development of the barley yellow dwarf Infectivity Index that takes account of sowing date in calculating spray need has indicated that few crops for harvest in 1982, other than those sown by early October or in high risk situations, will respond to aphicide sprays.

We are progressively improving our understanding of spore dispersal by wind and in splash droplets. The steep infection gradients characteristic of cereal mildew may largely be explained by dispersal in gusts of wind, with consequent greater impaction efficiencies than would be predicted from calculations based on mean wind speed. For splash-borne spores, results using simulated rain indicated that *Septoria nodorum* spores can be dispersed in airborne splash droplets, while dispersal of spores of the eyespot fungus seems to be restricted to larger droplet sizes behaving ballistically, explaining the restricted spread of the latter in field conditions.

Beet mild yellowing virus has been purified and an antiserum prepared that has been used to demonstrate virus in single aphids initially by ISEM and subsequently, at Broom's Barn, by ELISA, with the prospect of improving the sugar beet spray warning scheme. The discovery that deltamethrin, some analogues of the aphid alarm pheromone and the naturally occurring aphid repellent polygodial can decrease spread of potato virus Y experimentally in the field is an exciting achievement, offering for the first time the possibility of controlling the spread of economically very important non-persistent viruses chemically and furthermore by chemicals likely to be environmentally acceptable.

It is gratifying to report some progress with the difficult problem of viruses vectored by soil-borne fungi. We now have convincing evidence that red clover necrotic mosaic virus is transmitted by *Olpidium radicale* and preliminary results support the Japanese finding that *Polymyxa graminis* is the vector of barley yellow mosaic virus first reported in the UK in 1980. A recently discovered tubular virus apparently transmitted by *P. betae* is morphologically similar to beet necrotic yellow vein virus, responsible with its vector for the Italian-named 'Rizomania' disease of beet. The identity of our virus has yet to be established.

The discovery of large differences in the variability of isolates of the take-all pathogen made from rotational wheat as compared with those made from continuous wheat in 'take-all decline' has revived interest in the possibility that decline may be related to changes in the pathogen population. Whether these differences have pathological significance, however, remains to be investigated.

Experience with the highly efficient fungicide triadimefon, which shows the ability to control barley powdery mildew when present in soil at concentrations below that de-

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tectable by chemical means, suggests not only the possibility of its application by means other than directly to the crop by sprayer, but also the need to examine carefully the impact of residues in soil on the siting of experiments, especially on barley following crops treated with the fungicide. The sensitivity of the barley powdery mildew pathogen to very small concentrations of triadimefon is remarkable.

The significance of the undisturbed stubble of barley as a source of inoculum of *Rhynchosporium secalis* for many months after harvest has been demonstrated and also exploited in attempts to measure interplot interference by a splash-dispersed pathogen, extending in this context our investigations using barley powdery mildew, representing air-borne pathogens. Interplot effects were clearly indicated.

In studies of the epidemiology of chocolate spot of winter beans, we have early indications that simple means of measuring spore numbers of *Botrytis fabae* in crops might be valuable as an indicator of potential disease increase and hence perhaps of the need to apply control measures. Seed transmission of pea early browning virus was demonstrated in both field bean and broad bean this year, for the first time outside Poland and a severe stunting coupled with leaf necrosis, noted on field beans in 1980 has been ascribed to combined infection by two viruses, most often by bean leaf roll plus pea enation mosaic viruses but sometimes by bean leaf roll plus pea early browning viruses.

In experiments on potatoes we have shown that of the two *Fusarium* spp. commonly causing dry rot, *F. sulphureum* is more readily transmitted from seed to progeny tubers during the growing season than is *F. coeruleum*. Symptomless development of *Phoma exigua* var. *foveata* in potato stems has been shown to be more extensive following earlier infection and younger stems were more susceptible. The extent of invasion was revealed only after haulm desiccation and was positively related to gangrene incidence on tubers. Other experiments have shown that rate of wound healing which is important in control of gangrene differs with cultivar. An important finding for store management was that control of gangrene by fungicide applied 3 or 7 days after wounding was less effective on tubers stored at 15° or 20°C, as recommended for curing, than on those at 5°C during the interval.

The effects of the two sources of *Rhizoctonia solani*, seed tuber and soil on growth and yield of potatoes has been studied further. Soil inoculum delayed tuber initiation and therefore depressed early tuber yield, gave more tubers in the smaller size-ranges at harvest, and more than doubled the proportion of progeny tubers with black scurf, compared with seed tuber inoculum.

Aerobiology

Gradients of particle deposition in crops

Dispersal from point sources. Droplets of 18 μm diameter generated by a May spinning disc and labelled with thiabendazole were collected on horizontal and vertical plastic strips in a barley crop at successive stages in crop growth. First results indicate that gradients of deposition became progressively steeper as crop height increased, suggesting that reduction of disease by variety mixtures may depend in part upon the stage of crop growth when the pathogen is most prevalent.

Dispersal of barley mildew spores. In order to describe spore movement in crops adequately it is necessary to know whether spores are dispersed at all wind speeds or mainly in gusts (fast-moving, transitory parcels of air). For spores which are released and transported by gusts impaction efficiences will be greater than for those transported at all wind speeds and models purporting to predict deposition based on mean wind speed measurements will be inaccurate. Comparing spore deposition on cylinders of different diameters

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enables estimation of the wind speed when dispersal occurs. First results from studies in mildew-infected barley indicate that, within the crop, dispersal was by gusts and enhanced deposition accentuated the steepness of gradients near to the source. Deposition of spores arriving from further afield occurred at all wind speeds and gradients were less steep. A full report appears in Physics Department (p. 183). (Bainbridge, with McCartney, Physics Department)

Splash dispersal of *Septoria nodorum* spores. In still-air experiments the distribution of *Septoria nodorum* spores (average size 4×21 μm) within splash droplets was similar to that reported for spores of *Pseudocercosporella herpotrichoides* (2×50 μm) and *Pyrenopeziza brassicae* (4×11 μm) (*Rothamsted Report for 1979*, Part 1, 167–168). Most *S. nodorum* spores were carried in the larger ballistic splash droplets (diameter >25 μm) which travelled less than 1 m from the target spore suspensions (concentration, 8×10^5 spores ml^{-1}; depth 0·5 mm). When infected stubble (11×10^6 spores g^{-1} dry wt) was used as a target, splash droplets were smaller and contained fewer spores.

To investigate whether *S. nodorum* spores were carried in small airborne splash droplets suction samplers were placed at several distances downwind (mean windspeed 2·6 m s^{-1}) of target spore suspensions (concentration, 7×10^5 spores ml^{-1}; depth, 0·5 mm; area, 0·3 m^2) upon which simulated rain fell (rate, 10·4 litres h^{-1} m^{-2}, volume mean diameter, 6·6 mm). Airborne spores were collected as far as 10 m from the target, although more were collected nearer to it (Table 1). At a height of 40 cm above ground level the pre-impinger was a more efficient sampler for airborne *S. nodorum* spores than the cascade impactor or cyclone separator. (Brennan and Fitt).

TABLE 1

Number of airborne Septoria nodorum *spores collected by suction samplers downwind from a target spore suspension*

Distance from target (m)	Sampling time (min)	Pre-impinger (11 litres min^{-1})	Cascade impactor (17·5 litres min^{-1})	Cyclone separator (110 litres min^{-1})*
0·5	2	17	11	21
1·0	2	15	13	22
2·0	2	12	7	19
5·0	2	7	5	12
10·0	5	1	2	4

* Volume sampling rate

Dispersal of *Pseudocercosporella herpotrichoides* spores from infected straw by simulated rainfall. Wheat straws infected by *P. herpotrichoides*, yielding *c.* 50 000 spores per straw, were spread over an area of 0·3 m^2 upon which simulated rain fell for 15 min. Examination of samples from passive spore samplers placed at several distances downwind (mean windspeed 2 m s^{-1}) suggested that few, if any, *P. herpotrichoides* spores were dispersed to greater distances than in still-air experiments (*Rothamsted Report for 1979*, Part 1, 167–168). Vertical strips of fixed FP4 photographic film (Ilford Ltd), 7 mm wide, collected no spore-carrying droplets (diameter 150–1000 μm) beyond 1·5 m from the centre of the area of straws. Some smaller droplets (diameter <150 μm) were collected up to 5·5 m but these did not carry spores. Spores were splashed to heights of 40 cm in droplets collected on pieces of film placed horizontally at different heights at 0·6 m from the centre of the target. (Fitt and Nijman)

Effect of cellulose xanthate on dispersal of *P. herpotrichoides* spores. In preliminary experiments, spraying infected straw with cellulose xanthate, an anti-capping agent (manufactured as Vi-grow by Courtaulds Ltd, Coventry), considerably reduced splash dispersal

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of *P. herpotrichoides* spores by simulated rainfall. One hundred infected straws, yielding *c.* 11 000 spores per straw, spread over an area of 0·25 m² were sprayed with 25 ml of Vi-grow according to manufacturer's instructions; this approximates to the commercially recommended rate. Spores were collected on microscope slides placed at distances of 0·6, 0·8, 1·0 and 1·2 m downwind (mean windspeed 2 m s^{-1}), from the centre of the area of straws. During 15 min of simulated rain, eight slides collected 7500 spores from unsprayed straws compared with 1800 from straws sprayed 1 h before the experiment. In a similar experiment, in which sprayed straws (36 000 spores per straw) were left overnight before simulated rain commenced, the effect of cellulose xanthate on spore dispersal was even greater; eight slides collected 15 400 spores from unsprayed straws and 1800 from sprayed straws. (Fitt)

Properties of viruses and virus diseases

Beet mild yellowing virus (BMYV). Purification of BMYV was improved by differentially precipitating the virus at 4°C, from preparations made by methods developed previously (*Rothamsted Report for 1980*, Part 1, 181). The virus banded in CsCl gradients at the same position as best western yellows virus (BWYV), at a buoyant density of 1·422.

An antiserum was prepared which had a titre of 1/256 in immunodiffusion tests against purified virus and did not react with healthy beet or *Claytonia perfoliata* sap or with concentrated preparations made from *C. perfoliata*. The antiserum also reacted at 1/256 with BWYV, the respective immunoprecipitation lines fusing without a spur, indicating close relationship of the two viruses. This relationship was confirmed by the results of immunodiffusion tests using an antiserum to BWYV provided by Dr J. E. Duffus and by immunosorbent electron microscopy (ISEM) tests using the two antisera with sap extracts and purified preparations of the two viruses. ISEM tests on sap extracts (1g in 10 ml) resulted in 50–100 particles per field at 40 000× magnification. An antiserum to bean (pea) leaf roll virus (BLRV) from Dr J. W. Ashby also reacted with BMYV in immunodiffusion tests on purified virus and in ISEM tests on infected *C. perfoliata* sap, indicating a relationship between the two viruses. ISEM tests on sap extracts of BLRV-infected broad bean failed with both antisera possibly because the virus concentration was too low.

The BMYV antiserum has been used successfully in the diagnosis of field-infected beet by ELISA tests (Helen Smith, Broom's Barn) and also, using ISEM tests, for the detection of virus in aphids raised on infected plants. Grids prepared from untreated aphid extracts were difficult to interpret but following chloroform/butanol treatment particles were clearly defined and numbered about 100 per field at 40 000× magnification when ten aphids were extracted and five to ten per field when single aphids were extracted. The success of these tests suggests that it will be possible to develop rapid techniques for monitoring the proportion of infective aphids among those coming into a beet crop and so improve the spray warning scheme. (Govier and Woods)

Prevention of transmission of potato virus Y (PVY). In laboratory tests with apterous *Myzus persicae*, the pyrethroid deltamethrin (0·001 % a.i.) applied to infected tobacco leaves decreased transmission of PVY by S (insecticide-susceptible) and R_1 (moderately resistant) aphids to tobacco test seedlings by 50–60 % ($P < 0{\cdot}001$); at 0·01 % a.i. it decreased that of R_2 (highly resistant) aphids by 70 % ($P < 0{\cdot}001$). Application of 0·01 % a.i. deltamethrin to test seedlings diminished transmission by S and R_1 viruliferous aphids by 40–50 % ($P < 0{\cdot}01$) and by R_2 aphids by 30 % ($P < 0{\cdot}05$). Deltamethrin (0·001 % a.i.) also hindered acquisition of PVY from infected potato plants kept outdoors for at least 3 weeks after treatment and, in flight chamber tests, spraying infected tobacco plants with

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0·001% a.i. diminished transmission by R_1 alates to healthy unsprayed seedlings by 90% ($P<0·001$); spraying only the healthy test seedlings reduced it by 60%.

In a field of potatoes, cv. King Edward, two sprays of deltamethrin (12·5 g a.i. ha^{-1}) to plots with no infected plants originally present diminished incidence of plants with symptoms of primary infection with PVY (leaf drop streak) from 20 plants to six in sprayed plots ($P<0·01$); in plots with a row of infector plants there were 134 plants with leaf drop streak in unsprayed plots compared to 69 in sprayed plots; plots with either just the infector row or just the healthy plants sprayed had 76 affected plants ($P<0·001$). Results for tuber infection are not yet available.

One disadvantage of deltamethrin is that protection is less when insecticide-resistant aphids are vectors. Therefore, we have tested non-toxic behaviour-controlling chemicals as a means of preventing virus transmission irrespective of insecticide-resistance of the aphid.

The repellent polygodial (0·1% a.i.) diminished acquisition of PVY from treated infected leaves by about 80% ($P<0·001$), irrespective of whether S, R_1 or R_2 aphids were used as vectors; polygodial at 0·02% a.i. diminished acquisition by 50% ($P<0·01$). Aphid alarm pheromone derivatives also diminished acquisition of PVY from treated leaves, one by 40–50% and another by over 90% ($P<0·001$). With both of these the effect persisted for several days and was similar for S, R_1 and R_2 aphids. However, another aphid repellent, dodecanoic acid (0·5%) increased acquisition of PVY by about 30% ($P<0·05$). (Gibson, with Dawson, Pickett and Rice, Insecticides and Fungicides Department)

Virus transmission by fungi

***Red clover necrotic mosaic virus* (*RCNMV*).** The culture of *Olpidium radicale* associated with this virus has previously become dormant during summer. This year the infected clover plants were grown in cooled sand cultures and the fungus remained in an active stage throughout the summer months. Successive virus transmissions to clover have now been achieved by transfer of zoospores. On roots of mung bean seedlings necrotic lesions formed within 2 days of inoculation. RCNMV was identified in the necrotic tissues by ISEM test. No contaminating parasites have been noted and we conclude tentatively that RCNMV is transmitted by *O. radicale*.

***Barley yellow mosaic virus* (*BYMV*).** This soil-borne virus, first found and studied in Japan, has caused, in recent years, serious disease of winter barley in Continental Europe. In 1980 it was found for the first time in England affecting crops over a wide area, and again in 1981. In autumn 1980 fragments of root, infected apparently only by the plasmodiophorid *Polymyxa graminis*, the reported vector of BYMV, were taken from virus-infected plants grown in infested field soil and used as inocula for barley plants grown in sand. In March 1981 all inoculated plants were found infected by *P. graminis* and in April a few showed mosaic symptoms. Transfer of zoospores from one of these plants resulted in all inoculated plants showing symptoms, even in summer. This contrasts with observations in the field where mosaic symptoms disappear as summer approaches. Repeated observation has, so far, revealed only *P. graminis* in the roots and to this extent our results confirm the Japanese finding that *P. graminis* transmits the virus. (Macfarlane)

***A tubular virus associated with infection of sugar beet by* Polymyxa betae.** Sugar beet, grown in the glasshouse at 20–25°C in a Norfolk soil heavily infested by *Polymyxa betae* and intermittently flooded, sustained many root infections by the fungus. Root

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extracts were found to contain tubular virus particles of variable length, which were mechanically inoculated to leaves of *Chenopodium quinoa*, also kept at 25–25°C, forming pale chlorotic lesions that tended to become necrotic. Sugar-beet seedlings exposed to root washings from infected beet containing zoospores mostly of *P. betae* (though not entirely free from other parasites) became infected by both *P. betae* and the tubular virus. At lower temperatures, *c.* 15°C, few virus particles were seen in the roots. The virus seems similar to beet necrotic yellow vein virus (BNYVV) which is transmitted by *P. betae*. In Japan and S. Europe fungus and virus cause a serious disease of sugar beet usually known by its Italian name 'Rizomania'. Hitherto, neither BNYVV nor the disease have been identified in England or the other parts of N. Europe where *P. betae* is widespread. Whether or not our tubular virus is related to BNYVV, however, remains to be established. (Ivanović and Macfarlane)

Ryegrass mosaic virus (RMV). A field experiment was started at the Grassland Research Institute at Hurley in August 1979 to study RMV incidence in pure swards of Italian ryegrass (cv. RVP) and in mixed swards with perennial ryegrass (cv. Endura) or red clover (cv. Hungaropoly), sown in the proportions 1:2 and 2:1. Plots were harvested four times in 1980 and in 1981 and proportions of dry matter yield contributed by the components measured. Assessments of RMV and eriophyid mites (*Abacarus hystrix*, the only known vector of RMV, and *Aculodes dubius*) were made on Italian and perennial ryegrass separately. Virus infection was recorded on red clover.

Weeds were present in the first two cuts of 1980 and distorted the component yields but by the end of the year they presented no problem.

In May and August 1980, RMV was scarce on RVP and not seen on Endura. Of RVP tillers sampled before the final cut in October 1980, 8% showed RMV symptoms, increasing to 40% by March 1981. Infection of Endura was always less than 6%. The RVP/Endura mixture showed a smaller percentage of infected RVP tillers: in August 1980, March and September 1981, infection of RVP in the 1:2 mixture was significantly less than in the pure RVP plots. A corresponding increase in the percentage of Endura tillers infected in mixed relative to pure Endura plots was recorded in March 1981 only. By contrast, RVP mixed 1:2 with Hungaropoly showed a higher percentage infection than the 2:1 mixture or pure RVP in October 1980, although in September 1981 the opposite was true.

In both years few mites were found in the spring and considerably more in the autumn. Generally mites were more numerous and occurred on more tillers of Endura than RVP. Cutting temporarily decreased mite populations: after the cut in August 1980 mites on Endura increased from *c.* two per tiller 3 weeks after harvest to 60 per tiller 4 weeks later. Pure and mixed swards were difficult to compare because of much variation but Endura tended to have fewer mites in 1980 and 1981 and RVP fewer in 1980, but more in 1981, in mixture. Surprisingly, in 2:1 mixture with Hungaropoly, RVP generally had more and in 1:2 mixture fewer mites than pure RVP. (R. A. Gutteridge, with G. Lewis, Grassland Research Institute, Hurley)

Cereal diseases

Take-all on wheat after leys. A third successive winter wheat was grown in 1981 after different 2-year leys in 1977–78. Take-all was scarce on the first wheats and on wheat seedlings grown in soils taken after harvest before ploughing in 1979, but *Phialophora graminicola* (PG) was more abundant on the roots of these seedlings in soils after wheat following ryegrass or ryegrass–legume mixtures than following legumes alone (Table 2). None of the second wheat crops was severely attacked by take-all in 1980, but the disease

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was prevalent in 1981 when symptom severity and effect on yield were inversely correlated with the incidence of PG in 1979. Yields of all crops were much decreased by severe rabbit damage during winter and early spring.

TABLE 2

Take-all and grain yield of a third successive winter wheat crop in 1981 in relation to the incidence of Phialophora graminocola (*PG*) *after wheat in 1979 following different leys*

Crop 1977–78	% root pieces with PG on assay seedlings 1979	Take-all rating July 1981	Grain t ha^{-1} (95% DM)
Ryegrass	58	116	4·41
Clover	9	200	3·12
Lucerne	18	243	2·83
Ryegrass + clover*	51	126	4·67
Ryegrass + lucerne†	44	184	3·88

* Drilled mixture of ryegrass (cv. RvP) and clover (cv. Blanca)
† Alternate rows of ryegrass (cv. RvP) and lucerne (cv. Vertus)

The close negative correlation between the prevalence of PG and the subsequent development of take-all agrees with previous results from the Rothamsted ley–arable experiments (*Rothamsted Report for 1975*, Part 1, 255) but conflicts with results from other experiments reported last year (*Rothamsted Report for 1980*, Part 1, 185), a discrepancy we cannot yet explain. It is clear, however, that grass or grass–legume mixtures are to be preferred to legumes alone as a preparation for successive wheat crops. (Slope, R. J. Gutteridge and Swaby)

Cultural variation in the take-all fungus. The decline in the severity of take-all in wheat grown continuously is well documented but none of the proposed explanations of this decline has been generally accepted. Most involve the concept of biological control of *Gaeumannomyces graminis* var. *tritici* by other microorganisms but recent interest in the ability of some isolates of GGT to produce a fungal inhibitor (Romanos *et al.*, *Transactions of the British Mycological Society* (1980), **74**, 79–88) has revived suggestions that take-all decline may be a consequence of changes within populations of GGT. Results from a screening of isolates of GGT from wheat grown in contrasting rotations in the Highfield Ley-arable experiment suggest that some changes do occur. The incidence of three characters was recorded in cultures incubated at 24°C: (a) sectors and islands of variable growth on potato–dextrose–agar (PDA), not buffered; (b) slow growth (associated with inhibitor production) on PDA buffered to pH 4; (c) floccose growth on Lilly and Barnett's medium, not buffered. From wheat grown on land cropped only with wheat or barley for 10 years, 41% of GGT isolates 'sectored', 27% grew slowly and 54% were floccose. In contrast, 'sectoring' occurred in only 17% of isolates from wheat grown in a repeated lucerne ley–arable rotation and none grew slowly or was floccose. These marked differences suggest that further screening of GGT populations from other soils and cropping sequences may be rewarding but at present the possible ecological and pathological significance of the differences is unclear. (Slope and R. J. Gutteridge)

Effects of reduced cultivations on soil-borne disease. The incidence of diseases has been monitored on Letcombe Laboratory's long-term tillage experiments at Compton Beauchamp and Northfield sites since their inception. These experiments compare direct drilling (DD) with ploughing (PL) and additionally shallow tine (ST) cultivation is tested at Northfield. Initially a rotation of winter-sown wheat, oats, wheat and oilseed rape was used, allowing a large proportion of cereals to be grown relatively free from soil-borne

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disease. The success of this policy is shown in the results; on neither site did take-all exceed 6% plants infected nor eyespot 6% straws infected in any of the 3 years of winter wheat. The only significant diseases were brown foot rot at Northfield in 1976, where 30% straws were infected but not differentially with cultivations; and sharp eyespot at both sites in all 3 years, which tended to be greater after ploughing.

In 1980 it was decided to grow continuous winter wheat on these sites, which provided the opportunity to study the build-up of take-all on sites where different cultivation regimes were already well established. In 1981 take-all was prevalent on the second wheat crops at both sites but did not differ significantly with cultivations (Northfield DD 71%, PL 60% plants infected; Compton Beauchamp DD 70%, PL 77%). Eyespot was relatively well controlled by fungicide but sharp eyespot incidence was significantly greater after ploughing than direct drilling on both sites (Northfield DD 23%, PL 38%; Compton Beauchamp DD 6%, PL 20% straws infected). (Prew and Fox)

Residual effects of triadimefon in soil on barley mildew. Further studies confirmed and extended our earlier report (*Rothamsted Report for 1980*, Part 1, 186) that residues of triadimefon from a spray application (2 kg ha^{-1}) to soil can persist and decrease powdery mildew on spring barley. Georgie barley grown on this triadimefon-treated soil (Great Field 1) in 1981, 3 years after treatment, had significantly less mildew and greater yield (18%) compared with barley on untreated or benomyl-treated soil (Table 3). Mildew control was again effective though less marked throughout the growing season (from 13 April to harvest on 2 September), and the yield increase was smaller than in 1980, presumably reflecting diminishing residues with time. The soil was thoroughly mixed in 1980 and 1981 by chisel and conventional ploughing to a depth of 15 cm so triadimefon residues in soil in 1981 must have been much less than 1 $\mu g\ g^{-1}$ (1 ppm), assuming 1·8% $\times$ 10^6 kg soil ha^{-1} in the top 15 cm. Triadimefon has an adsorption coefficient (Kd) of 19·4 in soil from Summerdells I (which is similar to Great Field soil) so the amount available for uptake by barley plants in both years is unlikely to have exceeded 0·05 $\mu g\ g^{-1}$ (0·05 ppm). Chemical analysis of Great Field soil for triadimefon, using a method with a limit of detection between 0·02 and 0·05 ppm, failed to detect a difference between treated and untreated plots.

In subsequent experiments in Summerdells I, triadimefon sprayed on soil at rates $>0{\cdot}06$ kg ha^{-1} decreased mildew, but not yellow or brown rust, in barley growing in the soil 11 months later. In these experiments triadimefon, but not benomyl, imazalil or prochloraz (all at 0·5 kg ha^{-1}) significantly ($P<0{\cdot}01$) decreased mildew up to harvest and increased yield by 22%. Triadimefon incorporated into a different loam soil (6% organic matter) and a peat-based compost (14% organic matter) at rates $>0{\cdot}1$ ng g^{-1} significantly decreased mildew on Zephyr barley grown for 3 weeks in pots under warm glasshouse conditions.

Experiments on growing barley crops have indicated that at least half the normal recommended dose of triadimefon (125 g in 500 g Bayleton product ha^{-1}) applied commercially would reach the soil, resulting in the incorporation of 35 ng g^{-1} (0·06 kg ha^{-1}) into the top 15 cm of soil during susbsequent cultivations; under systems of minimum cultivation, or application to successive crops, greater concentrations would be expected in the surface soil. Our results indicate that under either growing system sufficient residues could persist to affect mildew on subsequent barley crops. Despite its strong adsorption to soil triadimefon or an active material deriving from it appears to remain available for uptake and translocation by barley plants over long periods. The apparent extreme sensitivity of barley mildew to small residues of triadimefon or a derivative will be used to develop a bioassay to explore further the implications of these results, particularly for field experiments at Rothamsted. (Rawlinson, Muthyalu and Cayley)

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TABLE 3

Residual effect of triadimefon, 3 years after soil application, on mildew and yield of spring barley. Great Field 1981

			Fungicide			SED ($n=8$)
			None	Benomyl	Triadimefon	
Grain yield (t ha^{-1})			3·99	4·18	4·70*	0·212
Straw yield (t ha^{-1})			2·62	2·70	3·07*	0·121
100 grain weight (g)			31·05	33·29	35·76*	1·228
% grain > 2·8 mm			53·9	62·6*	65·4*	4·15
100 ear weight (g)			79·4	89·5*	102·2*	3·99
Mean % mildew	(leaf 1 to 4)	17 June GS 25	0·9	0·6	0*	0·37
		1 July GS 60	16·7	13·1	1·7*	3·10
		15 July GS 80	44·0	39·8	16·8*[1]	4·32
	(leaf 1 and 2)	28 July GS 85	41·0	30·9	13·3*[2]	5·42

* Indicate values significantly different from untreated ($P<0·05$)
*[1], *[2] indicate values significantly correlated with grain yield ($P<0·05$) (1) $r=-0·44$, (2) $r=-0·50$

Sensitivity of *Erysiphe graminis* and *Rhynchosporium secalis* to triadimefon. The sensitivities to triadimefon of *Erysiphe graminis* f.sp. *hordei* and *Rhynchosporium secalis* were compared in a pot experiment in which the fungicide was mixed with a peat-based potting compost (14% organic matter) at rates from 0·1 ng g^{-1} to 10 μg g^{-1}. Spring barley seedlings (cv. Zephyr) were inoculated with *E. graminis* by shaking infected plants over them or with *R. secalis* by placing single 5 μl drops of a spore suspension containing *c.* 8×10^5 spores ml^{-1} in the axils of first seedling leaves. To prevent infection by *E. graminis* of seedlings inoculated with *R. secalis*, all seedlings were grown in filtered-air propagators (*Annals of Applied Biology* (1973), **73**, 9–13) with a capillary watering system. Under these conditions, triadimefon at small concentrations was less effective in controlling mildew than when plants were grown in the same treated compost but kept on glasshouse staging with water applied to the surface of the compost. Mildew on inoculated seedlings growing in untreated compost in the propagator became severe but was decreased by nearly 90% by triadimefon at 1 μg g^{-1}. Only 31% of seedlings inoculated with *R. secalis* developed symptoms but this was decreased to 6% by triadimefon at 100 ng g^{-1} or above. For both pathogens, however, 10 μg triadimefon g^{-1} was required for complete suppression of symptoms. (Jenkyn and Rawlinson)

Epidemiology of barley leaf blotch

Spore production of* Rhynchosporium secalis *on barley straw. After harvest of winter barley (cv. Maris Otter) on 6 August 1980, stubble samples of 100 straws were collected weekly to assess the production of spores of *R. secalis*. Straws were cut to a uniform length of 16 cm from the base and after washing, spores were counted on a haemocytometer. In late November, before ploughing, a bulk sample was removed to an adjacent site where it remained exposed to the prevailing weather. Viable spores were present on straws throughout the period from harvest to the following July. After harvest spore numbers rose to a mid-September peak of $21·8\times10^4$ spores per straw. During October numbers declined rapidly to $1·6\times10^4$ but later more slowly to $1·4\times10^3$ by late December. From January to mid-March numbers approximated to the detection threshold of the haemocytometer (*c.* 7×10^2 spores per straw) but then increased to a peak of $2·5\times10^4$ in early April. During May, June and July numbers declined: no spores were detected in August and sampling then ceased.

From January to late August straw washings were used to inoculate 200 pot-grown

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barley seedlings (cv. Marvis Otter) each week. Viable spores were present during January and February (mean 12% successful inoculations) even in samples yielding no spores on the haemocytometer. As spore numbers increased during spring successful inoculations rose to 87% but declined during the summer to 1% in late July, the last occasion on which viable spores were detected.

In mid-May, after autumn ploughing, spring cultivations and drilling with spring wheat, surface straw residues were collected from the original winter barley site. An equivalent weight to 100 16-cm lengths of stubble was washed and the suspension inoculated to 100 pot-grown seedlings: four lesions were produced compared to 80 from washings of stubble removed the previous autumn. (Stedman)

***Interplot interference by* R. secalis.** For the majority of foliar pathogens it is the gradient of spore dispersal that determines how far disease spreads from source: it also influences the rate at which disease increases within crops. However, local movement of spores is also important in experiments because transmission of inoculum between plots is a potential source of bias. In previous studies we have attempted to estimate the consequences of such interplot interference in experiments with the air-dispersed pathogen *Erysiphe graminis* (powdery mildew) on spring barley. We have now extended this work to include the splash-dispersed pathogen, *R. secalis*. With such pathogens a large proportion of splash droplets is likely to be deposited within a metre or so of the source, although some may travel longer distances. However, movement of even small amounts of inoculum between plots may assume significance if the opportunities for it to occur are numerous; a distinct probability in experiments with autumn-sown cereals.

In 1980–81 the effects of naturally-infected straw as inoculum and prochloraz sprays in autumn (22 December), spring (3 April), or both were tested on Maris Otter winter barley in a serially balanced design (*Rothamsted Report for 1974*, Part 1, 133), sown on 27 September 1980. Relative amounts of *R. secalis* in each plot were estimated by counting numbers of spores washed from sample plants; by exposing healthy test plants; and, at later growth stages only, by estimating areas affected by symptoms on the leaves. The straw proved a very effective source of inoculum and by late November, plant samples from inoculated plots yielded *c.* $1{\cdot}5 \times 10^6$ spores per plant compared to only $1–2 \times 10^4$ spores per plant from uninoculated plots. Similarly, test plants exposed in inoculated plots at about the same time developed approximately 16 times as many lesions as plants exposed in the uninoculated plots. Amounts of disease in the uninoculated plots not yet sprayed increased steadily during the winter and by mid-March had become as great as in the inoculated plots. Until mid-March, autumn-sprayed plots had less disease after spraying, than unsprayed plots (8×10^5 and 7×10^6 spores per plant respectively at the mid-March sampling) but by late April there was little difference between autumn-sprayed and inoculated unsprayed plots. The spring spray was probably applied too late for maximum effect but nevertheless decreased spore numbers in late April by at least a factor of ten.

The data have yet to be analysed, but samples taken in December from uninoculated and at that time unsprayed, plots immediately adjacent to inoculated plots yielded *c.* 2×10^4 spores per plant while those separated from inoculated plots by one and two plots yielded *c.* 1×10^4 and 3×10^3 spores per plant respectively, clearly indicating interplot effects. (Jenkyn, Stedman and Bainbridge, with Dyke, Field Experiments Section)

Barley yellow dwarf virus (BYDV)

Aphid infectivity and the Infectivity Index (II). Last year, as an aid to predicting the incidence of BYDV in autumn-sown cereals, we introduced the concept of an Infectivity

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Index (II) which is based upon the numbers of cereal aphids, mostly *Rhopalosiphum* spp., caught in the nearest Rothamsted Insect Survey (RIS) suction traps during the autumn and the proportion infective. We predicted that because the II, at the time of going to press, was the second largest recorded, infection by BYDV especially in September-sown cereals would be widespread in 1981 (*Rothamsted Report for 1980*, Part 1, 1982). Observations at Rothamsted and Woburn (*see* pp. 22, 27, and 32 of Multidisciplinary Activities) in wheat and barley showed that infection by BYDV was more common than for many years, especially at Woburn. Reports from elsewhere in Britain confirmed the importance of infection in September-sown crops in southern Britain and as far north as Lincolnshire. This included areas with no previous history of BYDV infection. The large area of cereals, especially barley, sown in September and the open, mild conditions which may have permitted aphid survival, and even multiplication, during the winter, contributed to the epidemic.

The II has been quoted in previous *Reports* as a total for the whole of the autumn cereal aphid migration. This is valuable for year to year comparisons but for each year a cumulative II, calculated weekly, is more valuable because it takes account of the overriding importance of sowing date to BYDV incidence. For the autumn migration in 1980 the weekly accumulated II is given in Table 4. Using this table the II can be obtained for any week at any time during the autumn migration. To assess the risk of infection the dates in the left hand column can be taken as crop sowing dates. This is for convenience as sowing dates are usually known whereas the date the crop emerges, and is exposed to infection, is known with less certainty. Therefore, using the table, the II for crops sown in the week beginning 22 September was 67 on 6 October and 88 on 2 November; for crops sown in the week beginning 1 September the corresponding figures were 174 and 195. However, as symptoms of BYDV infection take 2–4 weeks to appear in our test, the final Index can only be calculated 3–4 weeks in arrears, i.e. the final II for crops sown from 29/9–6/10 cannot be given until 27/10–2/11. While this might seem a serious restriction on the value of the II, spraying experiments by ADAS and others have shown that aphicides to control aphids and BYDV are most appropriately applied during the first 2 weeks of November. Evidence also suggests that crops sown after 10 October rarely benefit from an aphicide treatment. Therefore the II can provide information in time for a decision to be made on whether to spray.

While the larger the II the greater the risk of infection, results at Rothamsted suggest that an aphicide spray is warranted when this is greater than 50. Using this threshold in 1980, all crops sown up to 6 October (II = 64) would have benefited from treatment, but it would have been especially important to treat crops sown up to 21 September (II = 170); there was no need to spray crops sown after 5 October (maximum II = 22).

It is not known over what area the II calculated for Rothamsted is applicable. In the absence of any infectivity testing further east or north it can be regarded as an indicator of virus risk for E. Anglia and the East and South Midlands. Data for calculating IIs are also obtained at the Welsh Plant Breeding Station, Aberystwyth, and Long Ashton Research Station but it is most unlikely that the same II at each site will indicate the same risk from infection. Wherever calculated, the II should be used only as a guide and be interpreted in the light of local knowledge.

The II chart for 1981 is given in Table 5; the contrast with 1980 is striking. The maximum II is less than a tenth that recorded in 1980 and indicates that no crop, however early sown, needed aphicide.

For the first time this year the II has been provided nationally as a guide to the need for autumn aphicide. Some areas have been designated by ADAS as 'virus-prone' and here early-sown cereals may benefit from control measures irrespective of the II. It is suggested that for other areas the II is used as an indicator of virus risk.

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TABLE 4

Cumulative weekly Infectivity Index (rounded to the nearest whole number) for BYDV in autumn 1980

Crop sown in week beginning	Infectivity Index on 7/9	14/9	21/9	28/9	5/10	12/10	19/10	26/10	2/11
1/9	14	26	107	131	174	185	192	195	195
8/9		12	94	118	161	172	179	182	182
15/9			81	106	148	160	167	170	170
22/9				24	67	78	86	88	88
29/9					43	54	61	64	64
6/10						11	19	22	22
13/10							7	10	10
20/10								3	3
27/10									0

TABLE 5

Cumulative weekly Infectivity Index (rounded to the nearest whole number) for BYDV in autumn 1981

Crop sown in week beginning	Infectivity Index on 6/9	13/9	20/9	27/9	4/10	11/10	18/10	25/10	1/11
31/8	7	10	10	10	13	13	15	15	15
7/9		3	3	3	6	6	8	8	8
14/9			0	0	3	3	5	5	5
21/9				0	3	3	5	5	5
28/9					3	3	5	5	5
5/10						0	2	2	2
12/10							2	2	2
19/10								0	0
26/10									0

Spring and summer infectivity 1981. Infective *Rhopalosiphum* spp. and *Sitobion* spp. were caught earlier, 15 May and 22 May respectively, than for many years, probably reflecting the widespread infection in autumn 1980 and the mild winter. Very few *Metopolophium* spp. were trapped and none transmitted BYDV. Aphid populations were slow to increase and in consequence spring cereals which were generally sown earlier than last year were little affected by BYDV although later sown crops were affected more.

Of all cereal aphids tested in May, June, July and August 1·7, 4·2, 5·3 and 6·5% respectively proved infective. From 17 to 31 August, 10% of all aphids caught transmitted BYDV to test plants. This was a smaller proportion than in 1980 possibly because so little of the spring-sown crop was infected.

Sources of BYDV. Perhaps one of the most surprising results to emerge from live trapping and infectivity testing is the relatively small proportion of aphids caught that is infective. The proportion infective in the summer is probably determined by the levels of infection in cereal crops but the autumn migrant cereal aphids, which are almost exclusively *Rhopalosiphum* spp., presumably come from perennial grasses and perhaps, locally, from maize. Even in 1980 only 7·6% and in 1981 only 5·2% of all aphids trapped transmitted BYDV. These small percentages may result in part from the unlikelihood of sexual forms transmitting BYDV to cereals. However, another partial explanation was indicated by our finding that the concentration of BYDV, determined by enzyme-linked immunosorbent assay (ELISA), was less in maize and grasses than it was in wheat, barley and oats (*Rothamsted Report for 1978*, Part 1, 211).

When Julia barley, Blenda oats, Flanders wheat and S.22 Italian ryegrass were com-

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pared as sources of BYDV isolate B, known to be transmitted most efficiently by *R. padi*, there was no difference in the ability of *R. padi* to acquire virus but *S. avenae* acquired virus much more efficiently from barley than from the other three hosts. In these experiments the aphids used were maintained on Blenda oats. When a comparison was made between the ability of aphids bred on ryegrass to acquire BYDV from grass and those bred on oats to acquire BYDV from oats the latter combination was much more efficient. After 24 and 48 h acquisition feeds on grass 42 and 70% of *R. padi* bred on grass transmitted; when oats were the source of aphids and virus the corresponding figures were 92 and 100%, suggesting that ryegrass may be a poorer source of BYDV than oats. (Plumb, Lennon and R. A. Gutteridge)

Diseases of grain legumes

Spore catches and chocolate spot development on field beans. In a plot of winter beans, cv. Throws MS, from April onwards an attempt was made to relate chocolate spot (*Botrytis fabae*) development to 3- or 4-day spore catch and weather. (The plot was sprayed with benomyl in February when the disease threatened to kill the crop but was untreated thereafter.) Leaves at every third node on ten plants were tagged when fully unfurled and the percentage area of each leaf affected by spots or spreading lesions was assessed twice weekly. Spores were collected within the crop on a sticky cylinder (5 mm diameter) supported vertically just above the canopy, on a sticky microscope slide placed on the ground and protected by a rain shield and in a 500 ml beaker open to rain and run-off water from leaves. Young pot-grown plants were also placed in the crop with the traps, then returned to a cool greenhouse for 3–4 days for lesions to develop.

In the crop new infections, shown by fresh spotting, occurred on all tagged leaves on two occasions, 8–12 June and 21–26 July, but spreading lesions ('aggressive' disease) occurred only during the latter period. Both infection occasions were accompanied by large spore catches and were associated with periods of persistent rain. A 10-day period of rain in May did not produce many spores or new lesions but may have occasioned a slow build-up of inoculum which gave the large increase in June. Spells of rain lasting up to 2 days following dry weather did not increase spore catches or produce infections.

The sticky cylinder and slide caught approximately equal numbers of spores (*c.* 3 cm^{-2}) early in crop growth when plants were small; disease at this time was slight. However, as the crop grew, progressively fewer spores were caught on the cylinder and progressively more on the slide so that during the spell of severe disease in late July over 50 times as many were caught on the slide (*c.* 44 cm^{-2}) as on the cylinder. Infections on exposed plants followed the same trends as spore catches on the sticky slide suggesting that either might be used as an indicator of potential disease increase. The beaker was not a useful trap; the presence of much debris prevented reliable counting of *B. fabae* spores. (Bainbridge and Creighton)

Effects of benomyl on chocolate spot of field beans. In the multidisciplinary experiment on winter beans (p. 34) 'Benlate-T' seed dressing (a.i. benomyl+thiram) prevented the aggressive development of *Botrytis fabae* in February–March which killed most seedlings in untreated plots. A mist chamber experiment in the glasshouse showed that benomyl alone applied to the seed at 2·2 g a.i. kg^{-1} did not decrease the number of infections following inoculation of plants with a spore suspension (*c.* 7% of leaf area affected) but extension of those lesions was virtually prevented on leaves at the lowest three nodes (untreated plants *c.* 25% of leaf area, treated plants $<1\%$). Later, on leaves at node five, enlargement of lesions from later inoculations was as extensive on treated plants as on those untreated (*c.* 15% of leaf area). (Salt and Bainbridge)

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Detection of seed-borne viruses in *Vicia faba*. Tests on several broad bean and field bean seed lots known to be infected with broad bean stain virus or broad bean true mosaic virus (syn. Echtes Ackerbohnenmosaik) showed that infection could readily be detected in batches of seed (10–100 seeds per batch) by ISEM. Previously the only method of detecting these viruses in seed lots has been to grow-on samples of seeds and examine the seedlings for symptoms at intervals for 6–7 weeks after emergence. However, ISEM can detect infection in seed lots carrying as little as 0·1–0·5% infected seeds within 24–48 h, including the time required to soak the seeds prior to grinding. The amount of infection detected by ISEM is consistently greater than that detected in growing-on tests on the same seed lots, possibly because some seeds contain virus which does not infect the seedling. (Cockbain and Woods)

Seed-transmission of pea early browning virus (PEBV) in *Vicia faba*. No infection with PEBV was detected in 200 field bean seedlings cv. Minden grown from seed harvested from a naturally-infected crop but seed-borne infection was detected in two of 199 seedlings cv. Maris Bead and in one of 20 broad bean seedlings cv. Threefold White grown from seed of experimentally-infected plants. The infected seedlings were without symptoms. Seed transmission of PEBV in *V. faba* has previously been reported only in Poland. (Cockbain and Woods)

Virus-induced necrosis in field beans. Plants showing stunting, leaf malformation and necrosis were observed in a crop of field beans grown for seed at Woburn in 1980. Tests on a random sample of such plants showed that some were infected with two persistent aphid-borne viruses, bean leaf roll (BLRV) and pea enation mosaic (PEMV), whereas others were infected also with the nematode-borne pea early browning virus (PEBV). In glasshouse tests in 1981 field beans with any one of these viruses showed no necrosis and plants infected with PEBV alone were usually symptomless or showed a mild mottle only. However, infection with BLRV and PEMV together almost invariably induced severe stunting and leaf necrosis (reddish-brown necrotic spots and streaks) and infection with BLRV and PEBV together sometimes induced vascular necrosis. In contrast, plants infected with PEMV and PEBV together showed symptoms only of PEMV. Thus it seems that the necrosis seen in the field in 1980 was induced in some plants by an interaction between BLRV and PEMV and in others by an interaction between BLRV and PEBV. (Cockbain and Calilung)

Other work on grain legumes is reported in Multidisciplinary Activities, pp. 32–36.

Biodeterioration

Late application of fungicides to winter wheat. Fungal populations on ears of winter wheat (cv. Maris Huntsman) were smaller than those found previously on spring wheat (*Rothamsted Report for 1980*, Part 1, 190) and increased from $28{\cdot}8 \times 10^2$ to $10{\cdot}6 \times 10^5$ propagules g^{-1} between ear emergence and harvest. Yeasts and yeast-like fungi such as *Aureobasidium pullulans* and *Hyalodendron* sp. were the dominant microflora up to GS 80–81 after which *Cladosporium cladosporioides*, *C. herbarum*, *Verticillium lecanii* and *Alternaria alternata* became predominant. On flag leaves, pink and white yeasts were dominant until senescence started, although *Cladosporium* and *Alternaria* spp. increased slightly after GS 75–76. At harvest 77% of plated grain yielded *Alternaria*, 63% *Cladosporium* spp., 43% *Epicoccum* and up to 5% *F. culmorum* and *Acremoniella atra*. The incidence of storage fungi was much greater than in previous years with 31% of grain yielding *Penicillium* spp. and up to 5% *Aspergillus* spp.

Fungicides were applied at GS 37–38 (carbendazim + maneb as 'Delsene M') to control

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foliar pathogens and at GS 50 or 60 ('Delsene M,' captafol, imazalil, benomyl or prochloraz) primarily to control superficial fungal saprophytes on the flag leaves and ripening ears.

The microflora of flag leaves was decreased by the early fungicide application but recovered to 70–80% of total fungal populations on untreated control plots by GS 55. Of the other fungicide sprays captafol had the greatest effect on flag leaf microflora, especially pink yeasts, with or without an early application of 'Delsene M'. On captafol-treated plots fungal populations remained smaller than those on unsprayed plots for 4–5 weeks.

The microflora of developing ears was unaffected by the early fungicide spray but benomyl, captafol and imazalil applied at GS 50 or 60 significantly ($P=0{\cdot}05$) decreased the total microflora for 4–6 weeks. Combinations of the early fungicid eand captafol, 'Delsene M', imazalil or prochloraz had a similar period of effectiveness. Populations of *Aureobasidium pullulans*, *Hyalodendron* sp. and *Cladosporium* spp. were most significantly ($P=0{\cdot}05$) affected by the fungicide sprays. 'Delsene M' and imazalil significantly decreased *Alternaria* populations, but only between GS 85 and 95. *Verticillium lecanii* was unaffected by fungicide treatments.

Yield was only slightly increased by the early 'Delsene M' spray while of the late treatments, benomyl and prochloraz significantly increased yield over untreated controls. Similarly, combinations of the early fungicide and 'Delsene M' or prochloraz significantly increased yield when compared with the early spray alone (Table 6). Individual spray treatments gave increases between 2 and 11%. Varying the time of application of the late spray had no effect on yield. (Magan and Lacey)

TABLE 6

Effect of early and late fungicides on the yield (t ha^{-1}) of winter wheat (cv. Maris Huntsman)

Late fungicide	None	Benomyl	Captafol	'Delsene M'	Imazalil	Prochloraz
No early fungicide	7·93	8·39	8·27	8·25	7·99	8·38
'Delsene M' early	8·00	8·40	8·34	8·59	8·24	8·59

SED=0·172

Effect of environmental factors on field and storage fungi. Studies have continued on the effects of water activity (a_w) and other environmental factors on growth and sporulation of field and storage fungi (*Rothamsted Report for 1980*, Part 1, 191). Fungi were grown on a wheat extract medium at 14 or 23°C, with a_w modified with glycerol in the range 0·80–0·98, in sealed chambers flushed weekly with gas mixtures to give concentrations of 0·14, 1, 5, 10 or 21% oxygen or 0·03, 5, 10 or 15% carbon dioxide. Concentrations at which linear growth was halved (ED50) were estimated.

Field fungi were all tolerant of low oxygen concentrations (Table 7) but only *Penicillium roquefortii* of the storage fungi. Usually storage fungi were most sensitive to oxygen concentration at low a_w. Increasing carbon dioxide concentrations to 5 or 10% often stimulated growth of both field and storage fungi but some inhibition was observed at 15% CO_2.

The onset of growth was increasingly delayed as oxygen concentration or a_w was decreased. For example, with constant 1% O_2 at 23°C *P. roquefortii* required 4 days to show visible growth at 0·98 a_w and 18 days at 0·85 a_w and *Aspergillus candidus* 3 and 13 days respectively. At constant a_w the effect of reduced oxygen concentration was less marked: at 0·95 a_w *P. brevi compactum* required 1 day with 21% O_2 and 5 days with 0·14% O_2 while at 0·90 a_w and the same oxygen concentrations *A. versicolor* required 2 and 9 days respectively.

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Sporulation occurred over a wide range of oxygen concentrations. However, of the field fungi, only *A. alternata* and *C. cladosporioides* sporulated with 0·14% O_2 while *Penicillium* spp. spored with all oxygen concentrations even at low a_w. By contrast, *A. repens* and *A. candidus* required a minimum of 1% O_2 at 0·85 a_w while with 10% O_2 and 0·80 a_w *A. repens* produced cleistothecia only. With smaller oxygen concentrations conidial sporulation was sparse and there was much floccose mycelium. The different carbon dioxide concentrations produced no observable effect on sporulation. (Magan and Lacey)

TABLE 7

Concentrations of oxygen required to halve linear growth of field and storage fungi (ED50) at 23°C

Water activity	0·98	0·95	0·90	0·85
Field fungi			(ED50 %)	
Alternaria alternata	2·8	<0·14	0·14	N.G.
Cladosporium cladosporioides	0·7	0·8	10	N.G.
C. herbarum	1·3	5·1	<0·14	N.G.
Epicoccum purpurascens	0·4	0·7	0·14	N.G.
Fusarium culmorum	0·14	1·6	0·14	N.G.
Storage fungi				
Penicillium brevi compactum	1·1	0·6	0·4	1
P. cyclopium	0·6	N.D.	5·2	13
P. hordei	1·1	3·2	1·25	12·5
P. piceum	4·1	6	10	N.G.
P. roquefortii	<0·14	<0·14	<0·14	<0·14
Aspergillus repens	0·6	2	5	11
A. candidus	0·45	1·0	0·95	5

N.G., no growth
N.D., not determined

Potato diseases

Susceptibility of cultivars to tuber soft rot. As part of a collaborative programme of work on blackleg and tuber soft rot with the National Institute of Agricultural Botany, Cambridge, and Scottish Crop Research Institute, Pentlandfield, the susceptibility of tuber tissue of some 25 different potato cultivars to *Erwinia carotovora* subsp. *atroseptica* and subsp. *carotovora* was measured by using whole tubers incubated in an anaerobic environment, a modification of a method described by Bourne *et al.* (*Potato Research* (1981), **24**, 409–415); and by potato slices incubated aerobically.

The whole tubers had a cavity, 3 mm diameter, 10 mm deep, drilled into each end which was filled with inoculum of either bacterium (10^8 cells ml^{-1}) and another at the waist for water control. Tubers were incubated for 5 days at 15°C in sealed plastic buckets from which air had been displaced by nitrogen (*Rothamsted Report for 1973*, Part 1, 142).

Tests in January made on tubers stored at 5°C showed remarkably consistent differences between cultivars in the amount of rotting especially with the most resistant Pentland Crown, Record and Drayton and most susceptible Pentland Javelin, Klondyke and Majestic. Tests using slices inoculated to demonstrate the reaction of cultivars to different inoculum concentrations and wound healing gave less clear cut results. Although the reactions of Klondyke and Drayton were similar to those using whole tubers, other cultivars like Record showed completely opposite reactions in the two tests. This is perhaps not surprising in the that in whole tuber test the wound healing processes of the tissues are suppressed by the anaerobic atmosphere and the slice test is evaluating host reaction in relation to degree of wound healing and to different numbers of bacteria. (Lapwood and Read)

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Epidemiology of dry rot (*Fusarium* spp.). In a field experiment in 1980 seed tubers of three cultivars were inoculated with *Fusarium coeruleum* or *F. sulphureum* or contaminated before planting by dipping in soil slurries containing 10^2, 10^4 or 10^6 spores ml^{-1}. After harvest, progeny tubers were damaged, stored at 10°C for 7 weeks and the frequency and cause of rots determined. *F. coeruleum* was not recovered from progeny tubers of any cultivar but on progeny of contaminated Pentland Crown seed (10^6 *F. sulphereum* spores ml^{-1}) *c.* 20% of wounds developed rots by this pathogen. Smaller numbers of Desiree and Maris Piper progeny tubers rotted from this seed treatment, while very small numbers of all three cultivars rotted from seed dipped in 10^4 spores ml^{-1} and from inoculated seed tubers rotting at planting. Tests on soil from around progeny tubers by a selective dilution plate method confirmed the transmission of *F. sulphureum*, but not *F. coeruleum*, from rotting seed or seed contaminated at 10^4 or 10^6 spores ml^{-1}.

In an experiment in 1981 Pentland Crown seed tubers were dipped in slurries containing 10^6 spores ml^{-1} of either *F. coeruleum* or *F. sulphureum* before planting. At monthly intervals from June to October, plants were sampled, soil adhering to progeny tubers was tested on selective dilution plates and, where possible, progeny tubers were damaged and stored at 15°C for 4 weeks and then examined for disease. Both methods demonstrated transmission of both species but more of *F. sulphureum* than of *F. coeruleum* in the September and October samples. (Lapwood and Adams)

Gangrene

Stem infection. In a field experiment in 1980 stems of Pentland Crown plants were inoculated with *Phoma exigua* var. *foveata* on four dates by binding to them cotton wool soaked in one of a range of concentrations of pycnidiospores in suspension using wax film. The earliest date of inoculation (late June) resulted in the greatest development of pycnidia after desiccation and the greatest incidence of disease in damaged progeny tubers. There was also an effect of spore concentration, 10^6 spores ml^{-1} giving the most disease and 10^2 ml^{-1} being indistinguishable from the water controls. In a pot experiment, a similar inoculation technique was used on stems of plants 4, 7 and 10 weeks after planting and stems were desiccated 2, 4 and 6 weeks after inoculation. Pycnidial lesions after desiccation were larger the longer the interval between inoculation and desiccation and were also larger following inoculation of the younger stems. (Adams)

Wound healing and tuber susceptibility. The rate of wound healing of potato tubers affects their susceptibility to storage rots. The speed of healing varies with tuber maturity and may also vary between cultivars. Desiree, King Edward, Maris Piper and Pentland Crown seed tubers sprouted in November or February or unsprouted were planted on the same date and progeny tubers were harvested on three occasions from August to October 1980 with haulm destruction 3 weeks before final harvest. The resistance to water loss of potato tuber discs healed for periods of up to 9 days at 15°C, 95% r.h. provided a measure of wound healing. Susceptibility of wounded tubers to gangrene infection was assessed in tubers inoculated before or after curing for 0, 3, 7 or 14 days at 15°C.

Tubers harvested in August healed wounds more quickly and were more resistant to infection than tubers harvested later irrespective of sprouting treatment. Maris Piper tubers had a faster wound healing rate than those of other cultivars and curing for 7 or 14 days after inoculation was more effective in decreasing disease incidence in this cultivar. (Marriott, with Potato Marketing Board, Sutton Bridge)

Fungicide treatment of tubers. Effects of delaying fungicide treatment on the control of gangrene were investigated using Pentland Crown tubers immersed in soil slurry con-

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taining *Phoma exigua* var. *foveata* at two arbitrary concentrations, the higher one ten times the lower, and given cut or cut and crush wounds. Tubers were treated by immersion in 0·1 or 0·01 a.i. suspensions of thiabendazole or imazalil immediately or after 3, 7, 14 or 21 days at 5, 10, 15 or 20°C before storage at 5°C for 12 weeks.

Curing tubers at 15 or 20°C for 14 or 21 days decreased gangrene on both wound types, but less so at the higher inoculum concentration. Similarly, treatment with fungicide was more effective at the high rate of application and at the lower inoculum concentration. Fungicides applied immediately after wounding prevented gangrene at almost all wounds but when applied 3 days later gave only 40–50% control. Increasing the interval before treatment resulted in more disease and treatment after 14 or 21 days was generally ineffective. Although gangrene was decreased by fungicide treatment 3 or 7 days after wounding, more rots developed on tubers stored at 15 or 20°C than at 5°C, suggesting that if treatment with fungicide is delayed it would be more effective in controlling gangrene if the tubers had been held in cool conditions in the interval. However, if the delay in treatment exceeds 7 days or so, curing at 15 or 20°C for 14 days will provide better control than treatment with fungicide. (Hide and Cayley)

Effects of stem canker (*Rhizoctonia solani*). Fungicide treatment of seed tubers with black scurf greatly decreased incidence of stem canker and stolon infection but seldom affected total yields (*Annals of Applied Biology* (1982), **100**, 105–116). In 1981 King Edward plants from sprouted seed with sclerotia (SD), without sclerotia (O) or without sclerotia but with cultures of *R. solani* applied to soil at planting (SL) were sampled weekly.

On 14 May, 4 weeks after planting, 40% of shoots had emerged in all treatments and percentage stems cankered were 1 (O), 45 (SD) and 49 (SL). At the start of tuber initiation 4 weeks later, respectively 6, 63 and 93% stems and 2, 31 and 45% of stolons were infected (1, 22 and 37% of stolons were pruned) by *R. solani*. With SD and SL inoculum, 30% of stolons from the first node on stem bases were infected (adjacent to the seed tuber); fewer stolons from higher nodes were infected on SD plants whereas more were infected from SL. For example, at node five, 24% (SD) and 64% (SL) stolons were infected.

Numbers of stems per plant were not affected by SD but were decreased by SL, and throughout growth mean height of main stems was about 5 cm less than from SD or O. Numbers of lateral stems were similar in all treatments. Compared with O, SL delayed haulm and tuber growth, decreased leaf area (by 26% on 16 June, 7% on 14 July) and increased the proportion of leaf area on lateral stems. Although SL delayed tuber initiation, all treatments bulked at the same rate and SL therefore decreased yield per plant by about 50 g throughout the season, representing 55% decrease in yield on 30 June and 4% on 1 September. SL decreased numbers of tubers up to the beginning of July whereas during August more tubers were initiated and at harvest, in mid-September, SL plants had more tubers <4 cm and slightly more 6–8 cm tubers. Black scurf affected 1% (O), 13% (SD) and 31% (SL) tubers. (Hide)

Potato virus diseases at Rothamsted. When counts were made at the end of June 1980 and 1981, plots planted with King Edward seed grown at Rothamsted in 1979 and 1980 contained respectively 0·5 and 0·4% potato virus Y (PVY) and 0·04 and 0·1% potato leaf roll virus (LR). In both years Desiree had 0·3% LR but was free from PVY while Pentland Crown was free from both viruses. Maris Piper (1980 only) had 0·3% PVY and 1·6% LR. Few *Myzus persicae* were caught in the Rothamsted trap in either year and only one current-year infection with PVY was found, in crops for 1982 seed. In 1980 much of the PVY infection was by the veinal necrosis strain. Variation in the amount of infection between experiments and restriction of symptoms to single stems in many plants suggested that spread of this strain had occurred late in the 1979 season or perhaps during chitting

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before planting in 1980. In 1981 symptoms of potato mop-top virus infection were unusually obvious and unusually prevalent, amounting to over 1% in King Edward. Last year's wet season probably accounts for the amount of infection and cool weather early this season for the clarity of the symptoms. (Govier)

Staff and visiting workers

The two staff changes during the year concerned G. A. Salt, who retired in November after 33 years' service, and Sally Gosling, who completed her work on potato black leg and soft-rot in January, supported by the Potato Marketing Board and was appointed to study aspects of eyespot development with the support of the Perry Foundation for 3 years from November.

E. Lester continued as Chairman of the British Crop Protection Council; was elected to the Council of the National Institute of Agricultural Botany for a further period of 3 years; appointed by ARC as a representative for a further period on the Sugar Beet Research and Education Committee; and accepted appointment to a reorganised Research Panel of the Home Grown Cereals Authority.

The Department demonstrated recent research on sugar beet viruses to members of the SBREC 'Open' Conference, when Rothamsted hosted this and the following 'Closed' meeting in July.

N. White was awarded the degree of M.Phil. of the University of London for his thesis on 'Effects of sowing date on barley powdery mildew'. A. Cottey, Susan Griffin and Lynda Heywood were sandwich course students while R. W. Dominy, S. Gingell, Caroline Mead and J. Nijman were self-supporting voluntary workers.

K. Delaney (ARC student) completed his studies and submitted his thesis on root diseases of legumes: N. Magan (United Nations Fellow) and Susan Marriott (CASE student, Potato Marketing Board) continued full-time research on microbiology of cereal grain and wound-healing of potatoes in relation to disease respectively.

Maryse Chabrol (France) joined the Department to study the effects of soil sterilants on the growth of maize for a higher degree and N. Katis (Greece) commenced post-graduate research on transmission of potato virus Y. A. Dharmaratne (Sri Lanka) received training in identification of fungi and actinomycetes.

P. H. Gregory continued his work in the Department at the invitation of the Lawes Agricultural Trust and visiting scientists included Miss Patricia Ahl from Switzerland (virus resistance and resistance-related proteins), Mrs Venus Calilung from the Philippines (aphid transmission of viruses), Mr M. Ivanović from Yugoslavia (soil-borne fungal vectors of viruses) and Dr B. P. R. Vittal from India, Commonwealth Bursar, working on aerobiology of plant pathogens.

A. J. Cockbain attended the Eighth Meeting of the International Working Group on Legume Viruses in Versailles on 10 and 11 August and presented a paper on bean yellow vein banding and its helper viruses. D. Hornby was appointed a consultant in wheat root diseases on a project based at the Brazilian National Wheat Research Centre at Passo Fundo, Brazil. J. Lacey spent the fall quarter in the Plant Pathology Department, University of Minnesota as a Hill Visiting Professor. I. Macfarlane visited laboratories in West Germany, Denmark and Sweden to discuss problems in the biology of lower fungi and of virus transmission by fungi. R. D. Prew went to Versailles, France, to attend an Anglo-French Liaison Group Meeting on minimal cultivations and cereal rotations and G. A. Salt visited Egypt, Lebanon and Syria in March and the Sudan in September at the invitation of ICARDA to see and discuss field work on *Vicia faba* and to present a review paper to an International Congress on Faba Beans in Cairo.

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