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ROTHAMSTED RESEARCH

Report for 1982 - Part 1

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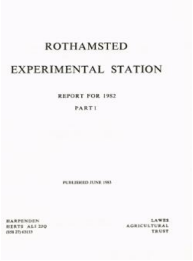
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REPORT FOR 1982
PART 1

Plant Pathology Department

E. Lester

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Introduction

Contrasts in the weather pattern with that of the previous season were reflected in different patterns of cereal disease. The cooler, wetter autumn of 1981 was associated with fewer cereal aphids, a very low Infectivity Index (II) for barley yellow dwarf virus and a forecast nil requirement for aphicide on autumn cereals. The prediction was essentially correct. The severe winter led to few *Rhopalosiphum* spp. surviving on grasses and for the first time this species was not the main early vector of BYDV. Wet weather delayed spring sowing and this, coupled with large numbers of other vector species, resulted in widespread infection in spring crops. The presence of a picornavirus in one of our cultures of *Rhopalosiphum padi*, the principal vector of BYDV, is of some interest and may be of practical significance in view of its occurrence in almost 20% of

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Rhopalosiphum spp. caught in our live aphid trap. Whether the virus affects fecundity or transmission efficiency requires study. An II, calculated for the first time for the East Midlands (ADAS Shardlow), suggests that the threshold index for spray need (50 at Rothamsted) will have to be calculated for each area. The II at Shardlow was more than ten times that at Rothamsted and it seems unlikely that our threshold value would apply in that area.

Exceptionally early and severe attacks of powdery mildew, associated with a hot dry spell in late April and May apparently obscured the expected benefits of cultivar mixtures in experiments and interplot interference was not evident. Much of the summer was dull and wet, with eyespot disease becoming exceptionally severe, the incidence and severity of sharp eyespot greater than usual and *Fusarium* ear blight obvious and widespread. The sharp eyespot picture was influenced by the greater susceptibility of the winter wheat variety Avalon. However the disease was less severe at Rothamsted than in many fields elsewhere in the region.

More effort is being devoted to the problem of barley yellow mosaic virus and other viruses vectored by soil-borne fungi. A first objective is to develop reliable and reproducible methods of transmission under controlled conditions and we have had encouraging results with the barley virus. The virus from sugar beet reported last year, associated with infection with *Polymyxa betae*, has similarities with fungus-vectored viruses of other plants but has been shown to be serologically distinct from those so far tested, including beet necrotic yellow vein virus, a tobamovirus involved in 'rizomania' disease of beet.

The inclusion of potato in the programme on PR-proteins has revealed the presence of at least one, following treatment with aspirin, though concurrent inhibition of virus has yet to be demonstrated. This discovery brings a little nearer the longer-term possibility of direct chemical inhibition of virus multiplication that could have significant practical benefit. Yet another approach, aimed specifically at the control of the non-persistent potato virus Y, holds more immediate promise, namely the use of aphid alarm pheromone derivatives and some pyrethroids that appear to interfere with virus transmission. Field experiments are planned on a substantial scale next year.

It is of considerable scientific interest that one type of sticky hair found on *Solanum berthaultii* has been shown to contain and to emit the aphid alarm pheromone (*E*)-β-farnesene in sufficient quantity to affect aphid behaviour. We believe this may be the first recorded instance of production by a plant of a compound, acting to protect the plant against aphids, that is also produced naturally by aphids themselves and functions as a mechanism for their preservation.

Further investigation of the residual and vapour effects of triadimefon have shown that the application of 2 kg ha^{-1} in August 1978 persisted in soil to the spring of this year in sufficient quantity to decrease powdery mildew on Georgie spring barley, though yield was not affected. Measurement of residual effects of triadimefon may be hindered in future by the emergence of resistant mildew populations. Vapour effects were apparent following spraying of a barley crop but not following spray application to bare soil. In experiments to identify factors determining the severity of eyespot lesions, preliminary findings indicate that high plant water potentials following infection may be important. If this is confirmed our ability to forecast the need for control measures may be improved, given good medium-term weather forecasts.

Immunospecific electron microscopy has proved a very sensitive technique in virology: its use for detecting seed-borne virus in *Vicia* bean shows that levels of infection can be detected in seeds that fail to produce infected seedlings. The relationship between seed infection as revealed by this technique and seedling infection needs further study. Insect transmission of broad bean mottle virus by *Apion vorax*, the vector of broad bean stain

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virus, and less efficiently by *Sitona lineatus*, has been demonstrated for the first time outside Portugal and the USA.

Spray timing experiments for the control of chocolate spot of field beans have indicated that increases in trapped spore numbers may be a useful criterion upon which to base advice on control measures. However, only one of the recorded spore flushes this year triggered a successful spray application, suggesting that weather subsequent to the spore flush is a major factor in disease development. The severity of bean rust in multifactorial experiments in which chocolate spot has been controlled by fungicides has cast some doubt on the general opinion that the disease is unimportant. The results of an experiment made this year showed yield increases of between a half and one t ha^{-1} following the use of rust fungicides.

Because of increasing concern about powdery scab on the part of potato growers and merchants, a programme was initiated to investigate the epidemiology of the disease both as a pathogen in its own right and as a virus vector. In particular, the effect of irrigation regimes for common scab control on the incidence and severity of powdery scab, known to be favoured by wet soil conditions, was investigated. Our results, in contrast to Australian experience, showed no increase in powdery scab from irrigation to control common scab on a sandy soil.

As part of an investigation into variety susceptibility to potato gangrene, a wound pathogen, the effects of fertilizer treatment were examined. Plots given 50% above standard fertilizer application produced tubers that were more susceptible to damage but, unexpectedly, less susceptible to gangrene. This apparent discrepancy was explained by the greater rate of wound healing shown by tubers from the heavily-fertilized crop.

Tests of fungicides and timing of application to potatoes destined for storage have shown that no one fungicide applied at one time can provide adequate control of the major rot and blemish diseases. The optimum timing varies with disease and with the conditions of storage, particularly temperature and moisture. However, for thiabendazole it is clear that treatment immediately after harvest is essential for control of gangrene and dry rot but less critical for skin spot, for the control of which an interval before treatment was sometimes advantageous, depending upon temperature and moisture.

At the request of the National Institute of Agricultural Botany, we are collaborating in experiments designed to develop reliable and reproducible tests for varietal susceptibility to black leg and tuber soft rot, bacterial diseases of major importance in seed production and stored ware respectively. Experiments involving seed tuber inoculation and irrigation suggest that a reliable test can be developed. Collaboration next year will extend to all the institutions in England and Scotland that have active research on these diseases.

Overseas collaboration has continued with the financial support of the Overseas Development Administration and significant progress has been made towards establishing the relationships between the Sumatra Clove Disease pathogen recently identified and other xylem-limited pathogenic bacteria. This collaboration has been extended to include Zanzibar, where a scheme has been set up by ODA to investigate the apparently similar "sudden death" disease which is widespread on the island.

Finally, it is with a marked feeling of frustration that I have to record the destruction of our newly-completed central media kitchen by an accidental fire at the end of October. The necessity for the kitchen was finally accepted as a high priority 5 years after the request was first made and an additional member of staff, part time, was appointed in order to satisfy demand on this central facility only 3 months prior to the fire. It is to be hoped that the damage can be put right speedily so that this much-needed service can be resumed and expanded. Meanwhile the incident has provided some salutory lessons for the Station's safety organization.

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Aerobiology

Particle dispersal in crops

Deposition to horizontal surfaces. Counts of pollens and spores collected in a barley crop on horizontal glass slides and barley leaves were compared with catches made using a cascade impactor operated isokinetically. Rates of deposition to horizontal surfaces always exceeded those calculated from particle fall speeds, sometimes three-fold. It is presumed that the enhanced deposition was a consequence of turbulent air flow presenting more spores to the surface than would occur by simple sedimentation. The degree of enhancement will need to be related to some parameter for turbulence to allow for this extra deposition to horizontal surfaces when modelling spore transport in crops.

Gradients of deposition. Using a May spinning disc to generate 20 μm diameter droplets, changes in gradients of deposition in a barley crop away from a point source have been plotted. As was expected gradients steepened as seedlings grew but, when leaf area index exceeded 1·0 and an almost closed canopy formed, further growth did not alter the gradient. Distribution of disease could, therefore, be influenced by crop growth stage at which first infection occurs.

Further experiments relating dispersal of barley mildew spores to wind speed indicate that, within crops, spores are only lifted from leaves when wind gusts penetrate the crop canopy. A consequence of distribution in gusts is enhanced deposition and this results in steeper gradients of deposit than when spores are released at all wind speeds. (Bainbridge and Stedman with McCartney, Physics Department)

Release and sedimentation of *Aspergillus glaucus* conidia. Members of the *Aspergillus glaucus* group are important in causing deterioration of cured tobacco leaf in Zimbabwe. Although the leaves are almost sterile after curing in temperatures $>65°C$, they absorb moisture and become contaminated with fungus spores within 24 h. An understanding of spore release and deposition could help in the development of practices that would decrease inoculum and increase safe storage periods for tobacco.

Release of conidia of *A. ruber* from conidiophores freshly produced on colonized tobacco lamina was studied by directing a jet of air from a tube 8 mm internal diameter onto the lamina lying flat in an 'ascospore-liberating tunnel' (Hirst & Stedman, *Annals of Applied Biology* (1962) **50,** 525–550). Jet velocities were varied between 0·18 and 5·8 m s^{-1} and the spores released were deposited on microscope slides in a cascade impactor. Below 2 m s^{-1}, conidial release was slow and only detected by sampling for 30 minutes. Above 2 m s^{-1}, 5 min samples were adequate. Over both ranges there were highly significant linear relationships between wind speed and $\log_{10}$ number of spores released. Although conidiophores twisted violently in a beam of light, there was no detectable difference in spore release between light and dark.

The sedimentation rate of *A. ruber* conidia was determined in a chamber like that used by Gregory & Henden (*Transactions of the British Mycological Society* (1976), **67,** 399–407). At ambient relative humidities, the sedimentation rate, calculated by the decay method was $1·38 \pm 0·146$ mm s^{-1}, equivalent to a unit density sphere 6·78 μm diameter. When the atmosphere in the chamber was humidified with damp towelling, the sedimentation rate was $1·90 \pm 0·135$ mm s^{-1}, equivalent to a unit density sphere 7·79 μm diameter. Because 96% of conidia were collected on stage 2 of the cascade impactor and the remainder were equally distributed between stages 1 and 3, the inertial method could not be used to give a second estimate but the measured diameter of the conidia averaged 6·29 μm. (Fisher and Lacey)

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Properties of viruses, virus diseases and virus vectors

Transmission of PVY and Beet Mosaic Virus (BMV) by cereal aphids. Aphid transmission tests confirmed that the cereal aphids *Rhopalosiphum padi* and *Metopolophium dirhodum* transmitted both PVY^O and PVY^N, although inefficiently. Transmission occurred in all combinations from and to potato and tobacco: *R. padi* was the more efficient vector. In the same tests *Sitobion avenae* failed to transmit either PVY^O or PVY^N. These three cereal aphid species were also tested for their ability to transmit BMV. All of them transmitted BMV inefficiently, *R. padi* being the most and *S. avenae* the least efficient. (Katis and Gibson)

Viruses transmitted by fungi

Barley yellow mosaic virus (BaYMV). The viruliferous isolate of *Polymyxa graminis*, (*Rothamsted Report for 1981*, Part 1, 190) vector of BaYMV, was maintained in young barley plants, cv. Maris Otter, grown in intermittently-irrigated sand cultures and inoculated with vector and virus by zoospore transfer. Inexplicably, fewer zoospores were produced than in 1981 but virus was, nevertheless, usually transmitted. In an attempt to devise a technique for testing cultivar susceptibility to vector and virus, newly-germinated barley seedlings were grown in nutrient solution for two days, transferred to a zoospore suspension for one day, then planted in potting compost. The proportion of plants that subsequently showed symptoms varied from 30 to 100%; incubation for one or two weeks at 8°C in a Saxcil cabinet sometimes hastened the appearance of symptoms; incubations in the glasshouse or a growth room at 19°C were equally good. Mechanical inoculation, either by rubbing or by spray gun, was also successful: again the proportion of plants that developed symptoms varied, from about 40 to 100%. The environmental conditions that determine systemic infection by BaYMV are still undetermined. Both fungal and mechanical inoculation are evidently effective and if they can be made consistently so, will enable further progress. (Shaw, Cox and Macfarlane)

***Viruses of sugar beet associated with* Polymyxa betae.** The virus, found last year in sugar beet grown in a Norfolk soil, (*Rothamsted Report for 1981*, Part 1, 190), was repeatedly transmitted in suspensions of *P. betae* zoospores from washed roots of plants infected by fungus and virus. Transmission from a single cystosorus makes it highly probable that *P. betae* is the vector but a recently-discovered contamination precludes certainty. Following mechanical inoculation local chlorotic lesions, that later became necrotic, developed on leaves of *Chenopodium album*, *C. amaranticolor*, *C. quinoa*, spinach and, less readily, sugar beet. No symptoms were obtained on other than chenopodiaceous plants. Electron microscopy of spray preparations from *C. quinoa* showed rod-shaped particles about 19 nm wide, with a central canal and a range of lengths with a main peak at about 150 nm, a smaller peak at 65 nm and a still smaller third peak at 300 nm. In ISEM tests the particles failed to react with antisera to the following tobamoviruses: tobacco mosaic virus; potato mop-top virus; wheat soil-borne mosaic virus; hypochaeris mosaic virus and three isolates of beet necrotic yellow vein virus (BNYVV) a component of 'rizomania' disease of beet.

Effects on growth of sugar beet, of both our original (1962) isolate of *P. betae* (*Rothamsted Report for 1965*, 122; *for 1973*, 124) and the new (1981) isolate with its associated virus, were measured on plants grown in sand. Infection decreased total dry weight to half or less than that of the uninoculated plants. The proportion, in the fibrous roots, of the total dry matter was 2–3 times greater in infected than in healthy plants. To what extent this effect resembles that described as 'rizomania' as a consequence of infection by

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P. betae and BNYVV is not clear. The 1981 isolate damaged the plants slightly more than the 1962 isolate.

An isolate of BNYVV from Yugoslavia produced symptoms on mechanically-inoculated chenopodiaceous hosts distinctly different from those produced by the Norfolk virus. We confirmed that *Beta macrocarpa* becomes stunted and excessively-branched when systemically infected by BNYVV. Within a month after manual inoculation to leaves of *B. macrocarpa*, leaf beet and spinach, BNYVV was detected in the roots. Virus-free zoospores of our original *P. betae* (1962) isolate were inoculated to the virus-infected roots. Subsequently, new zoospores, released from these plants and inoculated to roots of sugar beet, transmitted BNYVV, as demonstrated by infectivity test to *C. quinoa*. Thus BNYVV, which is not known to occur in England, can be acquired by an English isolate of *P. betae*. Both the Norfolk virus and BNYVV seem favoured by temperatures around 25°C.

Because in France TMV has been reported in association with BNYVV, we attempted to transmit TMV by *P. betae* but, in two experiments, the fungus failed to acquire the virus from systemically-infected spinach and transmit it to healthy spinach.

Experiments on *P. betae* alone showed that the time from zoospore infection till discharge of new zoosporangia was 60 h at 25°C, 76 h at 20°C, 96 h at 15°C and 10 days at 10°C. At 25°C cystosori formed in 8–10 days after inoculation by zoospores. In roots of seedlings growing in solution culture and inoculated with cystosori, zoosporangia developed within six days at 25°C. *P. betae* infected *Stellaria media* and *Claytonia perfoliata* but developed only to form zoosporangia; no cystosori have yet been seen in these hosts. This resembles the development, in certain hosts, of the related *Plasmodiophora brassicae* and *Spongospora subterranea* only to zoosporangia and not to resting sporangia. (Ivanović, Macfarlane and Woods)

Pathogenesis-related proteins

The effect of temperature on PR-proteins and virus spread. Injection of 1mM aspirin into leaves of *N. tabacum* cv. Samsun NN induced pathogenesis-related (PR)-proteins at 32°C and reduced the spread of TMV to surrounding tissue as measured by the size of lesions produced on subsequent transfer to 20°C. Similar treatment with polyacrylic acid at 14 μM did not induce PR-proteins and had no effect on the spread of TMV. In cultivar Xanthi-nc, both aspirin and polyacrylic acid induced PR-protein at 32°C and reduced the spread of TMV. At 35°C, polyacrylic acid induced little or no PR-proteins and did not affect the spread of TMV. (White and Woods with Antoniw and Carr, Biochemistry Department)

Serological relationships of PR-proteins. PR-proteins of *Nicotiana sylvestris* (b_0, b_1 and b_3) and of *N. tomentosiformis* (b_2) were purified using the procedure developed for the PR-proteins of *N. tabacum* cv. Xanthi-nc. The following serological identities were found using the antiserum to PR-1a of cv. Xanthi-nc in immunodiffusion reactions. PR-1a = b_0, PR-1a = b_1, PR-1b = b_2, PR-1c = b_3, $b_0 = b_1$ PR-1b = PR-1c (= indicates serologically indistinguishable). PR-1a was closely related but not identical to PR-1b and PR-1c. (White with Antoniw and Carr, Biochemistry Department and Ahl, INRA, France)

PR-proteins in potato. Standing detached stems of potato cv. Pentland Crown in a 5mM solution of aspirin for 7 days induced the production of a protein serologically related to the PR-1a protein from *N. tabacum* cv. Xanthi-nc. Aspirin treatment also induced a protein serologically related to PR-1a in both the A and Y types of *Solanum demissum*.

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Induction of PR-proteins and resistance to TMV by 2-thiouracil. Extracts made from leaves of Xanthi-nc and Samsun NN seven days after injection with a solution of 2-thiouracil (100 μg ml^{-1}) contained proteins PR-1a, PR-1b and PR-1c. Such leaves became highly resistant to infection with TMV and the few lesions that did form were considerably smaller than those on untreated leaves. (White with Antoniw and Carr, Biochemistry Department)

***Boerhaavia diffusa* inhibitor of virus infection.** Verma and Awasthi (*Canadian Journal of Botany* (*1980*) **58,** 2141-2144) reported that the root extract of *Boerhaavia diffusa* contained an inhibitor to virus infection. This inhibitor induced resistance to TMV infection in *Nicotiana glutinosa* and *Chenopodium amaranticolor* in both treated and untreated leaves. Using a *B. diffusa* extract kindly supplied by Dr. Awasthi we were unable to induce any resistance to TMV in untreated leaves in either species. However we did find the extract to be a powerful inhibitor of infection when mixed with the virus inoculum. (White with Antoniw, Biochemistry Department)

Production of (*E*)-β-farnesene, the aphid alarm pheromone, by the wild potato, *Solanum berthaultii*. The aphid alarm pheromone, (*E*)-β-farnesene, has been found in exudate from type B sticky hairs on the foliage of *Solanum berthaultii;* 1 g of leaves contained about 300 ng and 20 ml of air around this amount of leaf held within a syringe for 4 min contained about 50 ng, a concentration adequate to cause alarm response. Summing results from seven replicate experiments, one aphid (*Myzus persicae*) of 113 was disturbed by 10 ml air from a 20 ml syringe containing five potato leaflets (cv. Majestic) whereas 54 out of 99 were disturbed by air from a syringe containing five *S. berthaultii* leaflets of comparable size ($P<0{\cdot}001$). In parallel experiments, none of 106 aphids was disturbed by normal air from a syringe whereas air containing 50 ng (*E*)-β-farnesene disturbed 111 out of 132. Similarly of 48 aphids walking towards a Majestic leaf, 34 walked on to it whereas only six walked on to *S. berthaultii* ($P<0{\cdot}001$).

Alate aphids, the morph responsible for much virus spread, are reported to be particularly sensitive to (*E*)-β-farnesene and also to avoid landing on contaminated plants. *S. berthaultii* has already been hybridized with the cultivated potato and if the ability to produce (*E*)-β-farnesene can be introduced into cultivars, a useful degree of protection against aphids and, more importantly, limitation of virus spread may be obtained thereby. (Gibson with Pickett, Insecticides and Fungicides Department)

A virus from *Rhopalosiphum padi*. A report (D'Arcy *et al* (1981) *Virology* **112,** 346–349) of a picornavirus in *Rhopalosiphum padi* in Illinois prompted a search for similar particles in aphids in this country.

No virus was detected in extracts of a few grams of laboratory cultures of *Acyrthosiphum pisum*, *Aphis fabae*, *Metopolophium dirhodum* and *Sitobion avenae* or in individuals of *Rhopalosiphum maidis*. However, one of two cultures of *Rhopalosiphum padi* yielded moderate amounts of a 27 nm icosahedral particle. Some adults, showing more than 200 particles per field when tested by immuno-specific electron microscopy (ISEM) using an antiserum to the Illinois virus, produced some progeny in which virus was not detected. These progeny in turn produced some nymphs containing the virus. Seventeen of 92 clones of *Rhopalosiphum* spp. tested from the Rothamsted live suction trap catches contained the virus.

Purified virus had the same buoyant density (1·37 g ml^{-1}) in CsCl as the Illinois isolate and gave the same dilution end point when titrated in gel diffusion plates against the Illinois virus antiserum. There was no reaction with antiserum against barley yellow dwarf virus, the principal plant virus transmitted by *Rhopalosiphum* spp.

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Virus could be detected by ISEM in the honeydew from infected individuals and small amounts of virus were also detected in extracts of washed seedlings on which aphids had fed. However, preliminary work suggests that the virus does not multiply in oats, barley, wheat or ryegrass nor when injected into pupae of the honey-bee (*Apis mellifera*). (R. A. Gutteridge and Plumb, with Ball, Entomology Department)

Cereal diseases

Effects of *Rhynchosporum secalis* on winter barley. Last year we described work which aims to investigate the significance of inter-plot interactions occurring in experiments with *R. secalis* on winter barley (*Rothamsted Report for 1981*, Part 1, 195). As intended *Rhynchosporium* leaf blotch quickly became much more severe in plots inoculated with naturally-infected straw than in uninoculated plots. Plant growth was also greatly affected and by mid-February the average dry weight of seedlings from inoculated plots was *c.* 33% less than that of seedlings from uninoculated plots. We could not, however, be sure that this difference in seedling growth was due entirely to the effects of the pathogen rather than to other, direct, effects of the straw treatments. We have, therefore, compared disease development and seedling growth in uninoculated plots of winter barley (cv. Maris Otter) and others inoculated either with barley straw which was naturally-infected with *R. secalis*, barley straw which had been steam sterilized, or unsterilized wheat straw. The experiment was sown on 14 October and until at least the end of December there was significant leaf blotch only in those plots inoculated with infected barley straw. By early February it was present in most plots and thereafter continued to increase until by mid-April there were no differences between treatments. When the first samples were taken on 30 December the dry weights of seedlings differed little between treatments. However, in early February and mid-March, seedlings taken from plots inoculated with infected barley straw were 12 and 33% smaller, respectively, than seedlings taken from uninoculated plots. By mid-April the difference had declined to 16%. Effects of the other straw treatments were small and not significant. Plots inoculated with infected barley straw on average yielded less grain than uninoculated plots but not significantly so. (Jenkyn and Stedman with Dyke, Field Experiments Section)

Cultivar mixtures. There is now abundant evidence that the development of powdery mildew in mixtures of spring barley cultivars is commonly decreased relative to the mean for pure stands of the same cultivars. However, it can be predicted that if the mixtures are grown in small-plot trials (whether for evaluation or demonstration purposes) their performance may be adversely affected by inoculum emanating from neighbouring plots sown with the component or related cultivars. In a first attempt to measure the effects of interplot interference on the performance of cultivar mixtures we compared a commercial blend containing Claret (resistant), Athos and Koru (susceptible) with each of the components grown as pure stands, in a serially balanced design, using $2{\cdot}1 \times 18{\cdot}3$ m plots. As expected, mildew became severe on the Koru and remained relatively slight on Claret but there was little evidence of interplot effects. Surprisingly, there was also little evidence that mean amounts of mildew in the mixture were less than the mean of the amounts in the pure stands. The explanation for this may perhaps be found in the unusual earliness and severity of powdery mildew on spring barley in 1982: it was already prevalent by 11 May (GS 23), and by 25 May (GS 30–31) there was *c.* 34% mildew on third youngest leaves of cv. Koru. During these early growth stages there was probably little hindrance to the movement of inoculum, either within or between plots, so that the benefits of the mixture would have been small. At the later growth stages, the increased filtering effect of the crop would have been expected to hinder the movement of inoculum but it is

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possible that the disease was by then sufficiently severe (especially on cv. Koru), and hence inoculum concentrations sufficiently great, to preclude the expected benefit of mixing. Extended spore deposition gradients during the early growth stages might similarly explain our failure to detect interplot effects especially as the designs we use are only capable of detecting interactions between adjacent plots and these would be obscured if plots interacted with more than their immediate neighbours. (Jenkyn)

Residual and vapour effects of triadimefon. The vapour effects of the fungicide triadimefon are well known and recent observations at Rothamsted have shown the compound to be very persistent in soil (*Rothamsted Report for 1981*, Part 1, 193–194). These properties were further investigated in an experiment in which sprays of triadimefon were applied at the recommended rate (0·125 kg ha^{-1}), using a hydraulic sprayer, to fallow plots or plots of spring barley (cv. Atem, sown 2 April) on 21 May or 30 June. Chemical measurements and bioassays were used to monitor the fate of the compound. Development of mildew on inoculated barley seedlings (cv. Zephyr) exposed weekly in the centres of sprayed and unsprayed plots showed no evidence of a vapour effect after the first spray was applied probably because there was much rain soon afterwards. After the second spray, mildew development on seedlings exposed in sprayed barley for the first week after application was completely prevented but there was no vapour effect in sprayed fallow plots nor in any plot in subsequent weeks. Amounts of chemical deposited after the first spray, on filter discs exposed in the fallow plots and between rows in the barley plots, were similar. Even after the second spray when there was a well-developed canopy (GS 73) the concentration of chemical per unit area of soil between rows in the barley plots was still about 12% of that in fallow plots. Soil cores were taken to a depth of 15 cm from the plots on four occasions, and sown with seeds of mildew susceptible barley (cv. Zephyr) in a glasshouse containing mildew-infected plants of the same cultivar. Development of mildew on the seedlings showed that by 27 July there had been no detectable movement of the chemical beyond 3 cm down the soil profile. (Rawlinson, Jenkyn and Flavelle)

Long term residual effects of triadimefon in soil on barley mildew. Residual effects of triadimefon were first reported on spring barley grown on Great Field I. Continuing studies on this site have shown that sufficient residues remain to decrease powdery mildew in Georgie barley sown on 5 April four years after triadimefon was applied to soil (2 kg ha^{-1} on 22 August 1978). Mildew control was slight but significant up to 24 May

TABLE 1

Residual effect of triadimefon, 4 years after soil application, on mildew and yield o spring barley. Great Field 1982

		Fungicide			
		None	Benomyl	Triadimefon	SED (n=8)
Grain yield (t ha^{-1})		3·43	3·35	3·51	0·209
Straw yield (t ha^{-1})		3·22	2·83	2·68	0·272
1000 grain weight (g)		26·82	27·83	28·43*	0·633
% grain >2·8 mm		18·9	20·3	23·6	3·54
Mean % mildew (leaves 1 to 3)	24 May GS 31	1·7	1·7	0·7*	0·35
	7 June GS 48	8·7	11·5	7·0	2·52
	21 June GS 55	19·2	21·1	16·9	3·44
	5 July GS 85	42·4	38·5	36·7	4·52

* Values significantly different from untreated ($P<0·05$)

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and 1000 grain weight was increased (Table 1); neither grain yield nor other components of yield at harvest (16 August) were significantly affected.

Mildew control by triadimefon residues was also slight but significant up to 24 May in Georgie barley grown in other experiments on Summerdells I and in duplicate experiments with cv. Maris Otter winter barley on Long Hoos IV. Residues from sprays applied to soil at rates from 0·06 to 2 kg ha^{-1} two years earlier (29 August and 24 October 1980), which had effectively controlled mildew and increased yield in 1981, caused no significant increase in components of yield in 1982. Thus the effect on barley mildew of residues in soil continues to be detectable on all experimental sites but has lessened with time.

Triadimefon is also active against *Rhynchosporium secalis* (*Rothamsted Report for 1981*, Part 1, 194) and residues from sprays applied in 1980 at $>0{\cdot}5$ kg ha^{-1} decreased the number of Maris Otter leaves with *Rhynchosporium* lesions in some plots by up to 70%; as with mildew the effect did not persist beyond 7 June.

Tests (by D. Hollomon, Insecticides and Fungicides Department) of the triadimefon sensitivity of mildew isolates taken from treated and untreated plots in these experiments have shown that isolates from some treated plots were significantly less sensitive. The development of insensitivity, even in proximal mildew populations within one experimental site, could hinder future measurement of the long term residual effects of triadimefon because these measurements depend on bioassays: chemical techniques are not sufficiently sensitive. (Rawlinson, Muthyalu and Flavelle)

Factors affecting initiation and development of eyespot lesions on wheat. The coleoptile was the tissue most susceptible to infection by *P. herpotrichoides* when spore suspensions were inoculated on to different wheat tissues which were subsequently stained and examined microscopically. Although spores germinated to produce hyphae which grew on leaf blades, penetration and colonization were significantly ($P<0{\cdot}001$) less extensive than on the coleoptile. Spore germination and initial mycelial growth were similar on chlorotic leaves of plants kept in the dark and on green leaves of plants kept in the light indicating that the susceptibility of the coleoptile was not associated with lack of chlorophyll.

In experiments to determine the threshold number of spores required to initiate a lesion, there was some mycelial growth on the outer leaf sheaths of plants inoculated using filter paper discs dipped in spore suspensions of 10–10^3 spores ml^{-1} (up to 10 spores per disc) after four weeks incubation at 10–15°C. When plants were inoculated at *c.* 1000 or more spores per disc, the fungal mycelium had penetrated to the fourth leaf sheath in the same period.

When six isolates of *P. herpotrichoides* were grown on osmotically-adjusted potato dextrose agar (PDA) plates, mycelial growth was optimal at the highest water potentials (-5, -10 and -15 bars), even for isolates from the dryland areas of the USA. There was some growth at -69 bars after 14 days but none at -100 bars after 25 days. Differences in mycelial growth rates on PDA between isolates did not appear to be related to differences in pathogenicity to Armada wheat seedlings.

When plants, 10 per 14 cm pot of 1:3 sand/loam, inoculated with *P. herpotrichoides* spores (3×10^6 ml^{-1}) were watered with either 50 ml, 100 ml or 150 ml water per pot every three days eyespot lesions were most severe on the plants given the most water after 3–4 weeks. This suggests that high plant water potentials may encourage growth of *P. herpotrichoides* in the field. This may explain why a severe epidemic of eyespot developed in a naturally-infected crop of Armada winter wheat on the Rothamsted farm following a wet spring in 1982; 100% of the tillers were infected, 44% severely, at harvest although only 52% were infected, none severely, in April. (Higgins and Fitt)

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Barley yellow dwarf virus (BYDV)

Aphid infectivity and the Infectivity Index (II). Based upon the Infectivity Index (II) calculated for the autumn migration of cereal aphids in 1981 we predicted (*Rothamsted Report for 1981*, Part 1, 196) that no crop, however early sown, justified treatment with an aphicide in autumn to control BYDV. Observations at Rothamsted and Woburn (see Multidisciplinary Activities pp. 22, 23) and reports from other areas of Britain showed that this prediction was largely fulfilled. Infection by BYDV was negligible even on crops sown early in September: only in some crops, where the previous crop had been grass or where there had been many cereal volunteers, was serious infection seen. The II is based upon numbers of migrant aphids and their infectivity and cannot indicate the risk of infection to crops sown after grass or where there are many volunteers.

Evidence that cereals may be better sources of BYDV than grasses (*Rothamsted Report for 1981*, Part 1, 197–8) suggests that volunteers may be an especially important source of infective aphids in autumn. Seed shed from winter barley harvested in early July may quickly produce volunteers that can be infested by aphids migrating from ripening wheat and spring barley. Tests on a volunteer crop in October showed that 60% of plants were infected. If this is common the risk posed to crops sown nearby is obvious. It appears, therefore, that the trend towards early sowing of winter cereals may present problems not only resulting from crops at risk from infection but also by providing additional efficient sources of infective aphids.

Because it is not known to what area the II calculated at Rothamsted applies, this year, for the first time, the proportion of autumn migrants that is infective has been determined at Shardlow (Derbyshire) in conjunction with the Agricultural Development and Advisory

TABLE 2

Cumulative weekly Infectivity Index for BYDV in autumn 1982 (Rothamsted)

Crop sown in week beginning	Infectivity Index on									
	5/9	12/9	19/9	26/9	3/10	10/10	17/10	24/10	31/10	4/11
1/9	2	2	86	93	102	117	129	134	145	145
6/9		0	84	91	100	115	127	132	143	143
13/9			84	91	100	115	127	132	143	143
20/9				7	16	31	43	48	59	59
27/9					9	24	36	41	52	52
4/10						15	27	32	43	43
11/10							12	17	28	28
18/10								5	16	16
25/10									11	11
1/11										0

TABLE 3

Cumulative weekly Infectivity Index for BYDV in autujnm 1982 (Shardlow, ADAS East Midlands)

Crop sown in week beginning	Infectivity Index on									
	5/9	12/9	19/9	26/9	3/10	10/10	17/10	24/10	31/10	4/11
1/9	0	32	422	571	1122	1427	1607	1665	1709	1721
6/9		32	422	571	1122	1427	1607	1665	1709	1721
13/9			390	539	1090	1395	1575	1633	1677	1689
20/9				149	700	1005	1185	1243	1287	1299
27/9					551	856	1036	1094	1138	1150
4/10						305	485	543	587	599
11/10							180	238	282	294
18/10								58	102	114
25/10									44	56
1/11										12

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Service and an II calculated. The cumulative weekly II for Rothamsted is given in Table 2 and for Shardlow in Table 3.

Based upon the evidence that an aphicide spray is warranted when the II exceeds 50 at Rothamsted, the results in Table 2 suggest that all crops sown before 4 October would have benefited from an aphicide. The II was much larger than in 1981 (maximum II = 15) but was not as high as in 1980 (maximum II = 195) when infection was widespread and treatment was justified on crops sown up to 6 October (*Rothamsted Report for 1981*, Part 1, 196).

The II at Shardlow (Table 3) was more than ten times that at Rothamsted but as no previous measurements have been made in this area it is impossible to do more than speculate about the relationship between these figures and crop infection. It seems unlikely that the threshold figure of 50 will also apply to Shardlow but the large II recorded for crops sown up to 17 October suggests that there may be a considerable risk of infection. Because there is no previous experience to guide us we are uncertain whether crops sown from 18–24 October (II = 114) will benefit from an aphicide spray. Examining crops sown in the East Midlands this autumn will enable more reliable advice to be given in future.

The difference between the II at Rothamsted and Shardlow was due to seven times as many aphids, of which 50% more were infective over the whole migration at Shardlow (8·4%) than at Rothamsted (5·4%). The range of the weekly proportion infective at the two sites was 0–15% at Shardlow and 0–11·5% at Rothamsted. (Plumb, Lennon and R. A. Gutteridge with Agricultural Development and Advisory Service, Shardlow)

Spring and summer infectivity 1982. The severe winter weather probably killed most, if not all, individuals of *Rhopalosiphum padi* overwintering viviparously on Gramineae, with the result that this was not the first infective species as it usually is. It was surprising that the first infective species was *Metopolophium festucae* (19 May). This species has not been the first infective until this year and the spring migration of cereal aphids was remarkable for the large number of this species caught; it was the most numerous vector of BYDV in May and June. A single infective *Sitobion avenae* was caught on 21 May, but no more were infective until 2 July. Also in the first week of July, the first infective *R. padi* (6 July) and *M. dirhodum* (7 July) were trapped.

Wet weather delayed drilling of spring cereals and this, combined with the comparatively early appearance of infective aphids, resulted in quite widespread infection, especially of the latest-sown crops. Aphids migrating from ripening cereals were most numerous during the last week of July and 10% of the total of all species trapped at this time were infective. This indicates that, as there was so little infection of autumn-sown crops, a substantial proportion of the spring-sown crop must have been infected. (Plumb, Lennon and R. A. Gutteridge)

Sharp eyespot on wheat. This disease, caused by *Rhizoctonia cerealis*, has been recorded in many experiments at Rothamsted since it was first observed in 1935. Its incidence has varied greatly in different years but most stem infections have been superficial and confined to the lower internodes, even in crops with more than 50% of straws infected. Because of this we have believed that sharp eyespot seldom caused much loss of yield in wheat at Rothamsted. However, during July this year an apparently much more damaging attack was observed, especially on some of the recently introduced semi-dwarf wheats: extensive, multiple, pale lesions occurred on all internodes except the uppermost, the straws were brittle with the lumen often filled with *Rhizoctonia* mycelium. In most crops the disease was patchy and plants within patches ripened prematurely. A preliminary examination of the two winter wheat variety trials at Rothamsted showed that there was

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little infection on any cultivar in one trial (after potatoes) but there was some severe infection, varying with cultivar, in the other (after barley). From the latter, on 22 July, fifty plants were sampled from each of two plots of three cultivars selected to cover the apparent range of susceptibility. The five upper internodes of each straw were scored for sharp eyespot on a scale 0 (no infection) to 4 (severe). Average scores per straw were 1·54, 0·38, 0·19 for the cultivars Avalon, Norman and Huntsman respectively. Most infections on Huntsman were similar to those long familiar to us, so it seems that cultivar susceptibility as well as season was an important factor determining the unusual attacks this year. This seems to presage more serious damage by sharp eyespot in the future than in the past. (Slope and R. J. Gutteridge)

A secondary outbreak of take-all. There is little published information about the occurrence and significance of such outbreaks in cereal monoculture and the one that occurred in 1981 at Butt Furlong, Woburn, where continuous spring barley has been grown for 15 years is probably unique in its documentation. It is assumed that the first outbreak and peak of take-all occurred in 1969, the third consecutive year of cereals, because 42% of roots were infected on 21 July and soil infectivity about 1 July was more than twice that for similar periods in succeeding years (Table 4). Annual disease progress data are available only for 1969–71; after that disease was assessed only once each year. From 1970-80 there was little disease but in 1981 the greatest 1 July incidence of infected roots on field plants occurred, associated with increased soil infectivity, and in the following spring the March value for soil infectivity was the largest recorded (Table 4). There are insufficient data to decide whether disease was more or less severe than in 1969, nor is it possible to say that the low yield in 1981 was the result of take-all. Change of variety does not seem to be a likely explanation for the 1981 outbreak, which in a year generally favourable to take-all was more likely to have been determined by the weather.

TABLE 4

Take-all in continuous spring barley at Woburn

		Take-all			Yield[2]		
		% roots infected	Soil infectivity[1]				
Year	Variety	1 July	1 Mar	1 July	t ha^{-1}	SE	df
1969[3]	—	5·0	14	163	—		
1970	—	5·0	11	5	—		
1971	—	1·4	9	12	—		
1972–78	Julia to 1977 then Porthos	≤2·7	≤3	≤2	2·96[4]		
1979	Porthos	3·8[2]	19	4	1·98	0·183	5
1980	Georgie	0·6[2]	2	5	5·11	0·369	10
1981	Triumph	12·2[2]	2	61	2·79	0·519	11
1982	Triumph	n	31	33	5·65	0·421	12

1. Bioassay: number of infected roots per 750 cm^3 of soil in dilution series
2. Data from experiment CS/99, remaining data from adjacent strip, CS/40; continuous spring barley in both areas treated similarly
3. Second crop of spring barley after wheat
4. Mean over all years, range 1.42 (SE 0.341,(9 d.f.)—4.00 SE 0.328, (10) d.f.))

n To be assessed
— Not known

There must now be some doubt that the period between outbreaks was take-all decline (TAD), because the 1969 outbreak may also have been determined primarily by the weather, rather than cropping, and we were not able to demonstrate soil suppressiveness in tests made in 1980. On the other hand the site very quickly resumed its low level of

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disease after inoculum was added (*Rothamsted Report for 1980*, Part 1, 184). If it was TAD, then TAD may not provide adequate protection in all years against unacceptable losses from take-all. For this reason and also to assist in risk prediction it would be useful to have greater knowledge of the frequency, circumstances, causes and magnitude of secondary outbreaks. (Hornby and Henden)

Effects of recent and residual dazomet on yields and biomass in maize monoculture. In 1982 the effects of residual and recent applications of dazomet were tested on a twelfth crop of maize at Woburn. The yields were exceptionally low possibly because of poor emergence (68·6%) and waterlogging early in the season. During 1980 and 1981 the effects of dazomet applied annually from 1970 to 1979 had decreased markedly and treated plots differed little from controls. It was therefore unexpected when plots with residual dazomet and plots with recent dazomet also differed little and residual dazomet was more effective than it had been in 1981 (Table 5).

TABLE 5

Effects of recent and residual dazomet on the yield of a twelfth maize crop and on soil biomass and bacterial counts

Dazomet (450 kg ha^{-1})	Yield t ha^{-1} (DM 85%)	Biomass 20 July μg C g^{-1} soil		Bacteria g^{-1} rhizosphere soil 10 August × 10^{-6}
None	5·97	79·7	87·0	581*
Recent (Nov. 1981 only)	6·64	94·3		680*
Residual (Annually 1970–1979)	6·64	63·2	61·95	—
Recent + residual	6·85	60·7		332*
SED (rep.)	0·579(8)	8·65(2)	6·12(4)	

* transformed counts ($\log_e$) significantly different ($P=0·025$)
— not assessed

Biomass in plots with residual dazomet was significantly smaller than the biomass of plots that have never received dazomet, or were treated for the first time in 1981. Bacterial counts made three weeks later were positively associated with the biomass on 20 July (Table 5). Resumption of dazomet applications in 1981 resulted in a much longer-lasting effect on root-inhibiting fungi than was previously recorded (*Rothamsted Report for 1976*, Part 1, 267): *Trichoderma* spp. were still increased and *Microdochium bolleyi* still suppressed on 10 August. (Chabrol and Hornby, with Barnard, Field Experiments)

Biodeterioration

Late application of fungicides to winter wheat. Fungi colonizing flag leaves of winter wheat (cv. Maris Huntsman) were more numerous than bacteria, increasing from $6·4 \times 10^5$ to $2·9 \times 10^7$ colony forming units (CFU) g^{-1} between GS 53 and 87. The most rapid increase occurred between GS 75 and 85. By contrast, emerging ears (GS 53) became colonized mostly by bacteria, which increased from $1·5 \times 10^7$ at GS 53 to $3·1 \times 10^7$ at GS 90 while numbers of fungi increased from $6·3 \times 10^5$ to $5·6 \times 10^6$ CFU g^{-1} of ears. These populations of fungi were greater than those colonizing ripening ears of the same cultivar in 1981 (*Rothamsted Report for 1981*, Part 1, 199). Initially (GS 53), pink and white yeasts accompanied by smaller numbers of *Aureobasidium pullulans*, *Hyalodendron* spp. and a few *Cladosporium* spp. and *Verticillium lecanii* were found on both flag leaves and the emerging ears. However, *Hyalodendron* spp., present only until GS 85 on flag

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leaves, were isolated up to harvest from ripening ears. White yeasts, *A. pullulans* and *Cladosporium* spp. were most numerous on flag leaves until they senesced while on the ripening ears *V. lecanii* and *Cladosporium* spp. were most numerous. Although *Fusarium* spp. were detected only occasionally in 1980 and 1981, in 1982 both *F. culmorum* and *F. avenaceum* and sometimes *F. poae* were common and together were more numerous than *Alternaria alternata* on senescing flag leaves and on the ripened ears at harvest. Up to 84% of harvested grain was contaminated with *Cladosporium* spp., 56% with *Alternaria alternata*, 35% with *Epicoccum purpurascens*, 26% with *F. culmorum* and 18% with *F. avenaceum*. The incidence of storage fungi was high with 29% of grain carrying *Penicillium* spp. and 3% *Aspergillus* spp.

The effects of fungicides applied at GS 37–38 (carbendazim + maneb as 'Delsene M', to control foliar diseases) and GS 50 or 60 (captafol, 'Delsene M', imazalil, prochloraz or a mixture of benomyl and 'Kaskade' (maneb + mancozeb)) on the superficial fungal populations on flag leaves and ears were assessed. By the time the late treatments were applied any major effect of the early treatment had disappeared. Of the late treatments captafol and benomyl were the most effective decreasing total fungal populations on flag leaves significantly ($P < 0{\cdot}05$) for six weeks. Imazalil was effective for four and 'Delsene M' for two weeks, after which periods populations recovered to levels similar to those on the untreated plots. Prochloraz had little effect.

Fungicides had a smaller effect on the microflora of the ears than on that of flag leaves. Benomyl, captafol and prochloraz were all significantly effective ($P < 0{\cdot}05$) for two weeks: other treatments decreased populations for only 24 h. Populations of *A. pullulans*, pink and white yeasts, *Cladosporium* spp. and *Hyalodendron* spp. were most affected by fungicides. Little control of *A. alternata* or *Fusarium* spp. was detected on either flag leaves or ears.

Yields were not increased by the early 'Delsene M' spray and of the single late treatments, only captafol and benomyl increased yields over untreated plots. However when the early fungicide was combined with a late benomyl or 'Delsene M' treatment yields were significantly ($P < 0{\cdot}05$) increased over an early treatment alone, while all combinations of early and late sprays gave smaller increases over untreated control plots. Varying the time of the late sprays between GS 50 and 60 did not affect the extent of yield increases, which were mainly due to increased grain size. (Table 6.) (Magan and Lacey)

TABLE 6

Effect of early and late fungicides on the yield (t ha^{-1}) and 1000 grain weight (g) of winter wheat (cv. Maris Huntsman)

Late fungicide	None	Benomyl	Captafol	'Delsene M'	Imazalil	Prochloraz
			Yield			
No early fungicide	8·07	8·14	8·37	7·98	7·63	7·98
Early fungicide	7·75	8·64	8·17	8·45	8·29	8·39
SED = 0.364						
			1000 Grain Weight			
No early fungicide	41·4	43·7	43·8	43·3	41·6	42·9
Early fungicide	43·3	43·8	43·9	43·8	43·3	43·9
SED = 0.457						

Effect of environmental factors on interactions between field and storage fungi. Studies have continued on the ecology of wheat grain fungi (*Rothamsted Report for 1981*, Part 1, 200). The effect of water activity (a_w), temperature and substrate on the *in vitro* interactions between 16 field and storage species were determined. Fungi were grown on malt and wheat extract agars modified with glycerol to 0·98, 0·95 and 0·90 a_w. Pairs of fungi in all combinations were inoculated 2·5 to 3·5 cm apart and examined after 7, 14, 21 and

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28 days incubation at 15, 25 and 30°C. Fungal interactions were determined by direct microscopic and macroscopic examination and scored numerically thus: 1 mutual intermingling; 2 mutual inhibition on contact or space between colonies small: 3 mutual inhibition at a distance; 4 inhibition of one organism on contact, the inhibitor species then continuing to grow, though perhaps at a reduced rate, through the inhibited colony; 5 inhibition of one organism at a distance, the inhibitor species then continuing to grow through the resulting clear zone and the inhibited colony, perhaps at a reduced rate. An Index of Dominance (I_D) was calculated by summing the scores accorded to each fungus against all others and comparing I_Ds at each a_w and temperature combination. The total number of fungal pairings for each combination of a_w and temperature was 120.

Field and storage fungi demonstrated a wide range of interactions on both media. I_D varied with a_w, temperature and substrate. *Epicoccum purpurascens* and *Fusarium culmorum* were the only field fungi that competed successfully against other fungi on both substrates. *E. purpurascens* showed mutual antagonism with most storage species while *F. culmorum* mostly inhibited them either at a distance or on contact while itself continuing to grow. *Alternaria alternata*, *Cladosporium* spp. and *Verticillium lecanii* were all uncompetitive intermingling freely with many *Aspergillus* and *Penicillium* spp. Of the *Penicillium* spp., *P. brevicompactum* and *P. hordei* were the most dominant although *P. cyclopium* and *P. roquefortii* were competitive on malt and wheat extract, respectively. *P. piceum* was competitive against both field and storage fungi but only at 30°C. *Aspergillus* spp. were not competitive in these studies with the exception of *A. candidus* and *A. nidulans* at both 25 and 30°C and *A. fumigatus* at 30°C only: I_Ds were as high as for *Penicillium* spp. only when a_w was limiting and at high temperature. *A. repens* and *A. versicolor* were uncompetitive at most a_ws.

Usually as temperature was increased from 15 to 30°C, regardless of a_w, I_D changed markedly showing that the influence of temperature on the relative competitiveness of field and storage fungi is considerable. I_Ds of the most dominant fungi were often lower on wheat extract than on malt agar at all three temperatures suggesting that the competitive ability of some species was altered by nutrient source. Comparisons of I_D and linear growth rate showed that these were not correlated. For example, *P. brevicompactum*, with one of the highest I_D totals at 0·98 and 0·95 a_w and 15 and 25°C, especially on malt agar, had one of the slowest rates of growth. It dominated by inhibiting many fungi at a distance, indicating the release of inhibitory metabolites into the medium. Detailed microscopic observations of the interaction zones between hyphae of different fungi revealed a number of abnormalities, including granulation and vacuolation of hyphal cells associated with cessation of growth. Morphological changes and increased branching were also observed. However no changes in permeability of affected cells, loss of metabolic activity, or cell death, were detected. (Magan and Lacey)

Production of *Alternaria* toxins on wheat grain and agar is reported in the Chemical Liaison Unit report p. 138.

Diseases of grain legumes

Detection of seed-borne viruses in *Vicia faba* by ISEM. In further studies on detection of broad bean stain virus (BBSV) and broad bean true mosaic virus (BBTMV) in field bean and broad bean seed by ISEM (*Rothamsted Report for 1981*, Part 1, 199), BBSV was detected in ten and BBTMV in four of thirty-two seed lots (four samples of 25 seeds tested per seed lot). In these tests all seeds were soaked for 48 h prior to grinding in 0·06M phosphate buffer pH 6·5 (2 ml g^{-1} seed). Extracts from some infected seed lots contained many particles (50–100 per field seen in the electron microscope at a magnification of 40 000) and 0·6–2·8% seedling infection was detected when seed from some of these was

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grown-on in the glasshouse or field. However, extracts from other infected seed lots contained few (two per field or less) or apparently empty (fully penetrated by negative stain) particles and no infection was detected in progeny seedlings from these lots. Thus although ISEM provides a rapid means of identifying seed lots infected with BBSV or BBTMV, the relation between ISEM results and seedling infection needs further investigation. (Cockbain, Woods and S. E. L. Roberts)

Transmission of broad bean mottle virus by weevils. In glasshouse tests broad bean mottle virus (BBMV) was transmitted more frequently by *Apion vorax* than by *Sitona lineatus*. Thus 17% of *A. vorax* but only 3% of *S. lineatus* transmitted BBMV when caged for four days on healthy seedlings. When caged for one day on infected plants and then on a series of seedlings, 16% of *A. vorax* transmitted on the first day of leaving the infected plants, 4% did so on the second day but none transmitted on the third or fourth days. Transmission of BBMV by insects has previously been reported only in Portugal and the USA. No seed transmission was detected. (Cockbain)

Other work on grain legumes is reported in Multidisciplinary Activities (pp. 33–39).

Chocolate spot of beans. In an experiment relating spray timing to crop and disease progress, increases in disease occurred during four periods (21 January–1 February; 26 February–5 March; 8 April–19 April; 21 May–22 June). These were periods of heavier rainfall and each was accompanied by increased spore catches on traps. In a replicated experiment single sprays (benomyl, 500 g a.i. ha^{-1}) were applied either according to spore catch or crop growth as shown in Table 7.

TABLE 7

Effect of spray timing on the yield of winter beans

Spray date	Spray timing*	yield (t ha^{-1})
25 Jan	early crop growth	2·45
19 Mar	1st spore peak	2·36
22 Apr	2nd spore peak	2·44
29 Apr	early flowering	2·58
11 May	mid flowering	2·60
26 May	3rd spore peak	2·94
7 Jun	4th spore peak	2·45
untreated		2·45
		SED 0·11

*timing related to crop growth or spore catch

Disease increases early in the year were not followed by continued development so early sprays had little effect on disease amounts. Only during the long period of disease development of May–June, was the effect of sprays noticeable. Assessments on 7 June showed that plants sprayed on 22 April, 29 April, 11 May or 26 May had 14·0, 9·6, 10·7 and 7·0% respectively of the area of leaves near mid-stem height affected by aggressive lesions compared with 59·2% on untreated leaves. The numbers of nodes defoliated were 11·9, 11·5, 9·1 and 9·6 compared with 12·9 on untreated crop. The spray applied on 26 May also decreased spotting on upper leaves (0·9% area affected compared with 2·4% on untreated) and was the only spray to increase yield significantly, much of which was attributable to an increased number of pods per stem (3·6 against 3·2 on other treatments). No treatment affected number of stems or average seed weight.

Although the spray timed according to the third peak in spore catch gave best control of disease and the best increase in yield, it is not possible, without good medium term weather forecasts, to decide which flush of spore release is likely to lead to prolonged

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disease development and thus which step in the epidemic it is most profitable to control.

Isolations made from diseased leaves through the season yielded mainly *Botrytis fabae* and tests made at the beginning and end of crop growth showed no evidence of the development of resistance to benomyl. (Bainbridge, Cayley and Creighton)

Bean rust. Rust (*Uromyces fabae*) is generally considered not to limit the yield of spring-sown field beans (*Vicia faba*) because the disease appears late in the season when healthy leaves are often few. The multidisciplinary experiments have shown that controlling other pests and diseases prolongs the life of leaves into a period when rust attack might be damaging (*Rothamsted Report for 1981*, Part 1, 35).

An experiment was therefore made to measure the effect of rust in spring beans (cv. Minden) sprayed twice with permethrin and once with pirimicarb to control insects and viruses. Small plots (4 rows 51 cm apart × 3 m) were used to compare combinations of benomyl sprays to control chocolate spot (*Botrytis fabae*); and rust fungicide sprays (maneb/mancozeb or propiconazole) applied twice or three times with untreated controls.

Rust was established on winter beans by mid-June and had developed to epidemic proportions by early July (see Multidisciplinary Activities, p. 36). In the spring bean experiment first rust pustules were seen on 7 July and first rust sprays were applied on 9 July to be followed by further applications on 23 July and 13 August; for the two-spray treatment the middle application was omitted. Benomyl was applied on 2 July and 13 August.

TABLE 8

The effect of rust control on yield of spring beans

	Rust Fungicide				
	None	Propiconazole		Maneb/Mancozeb	
		2	3	2	3
(a) Chocolate spot*					
No benomyl	1·1(2·8)	1·0(0·5)	0·9(0·6)	0·6(0·7)	0·5(0·8)
Benomyl	—	0·5(0)	0·7(0)	0·4(0·3)	0·4(0·3)
SED 0·23(0·81)					
(b) Rust*					
No benomyl	5·2	1·4	1·3	1·9	1·2
Benomyl	—	1·1	0·4	1·2	1·2
SED 0·73					
(c) Yield (t ha^{-1})					
No benomyl	4·51	5·06	5·30	5·05	5·50
Benomyl	—	5·28	5·92	5·67	5·63
SED 0·276					

*Top 5 leaves of plant; per cent leaf area affected by spotting, and by aggressive lesions in parentheses.

The mean per cent leaf area affected by disease in early August for the uppermost five leaves is shown in Table 8. Benomyl decreased the incidence of chocolate spot and especially the aggressive phase. Rust sprays were effective especially when applied three times and by mid-August, when untreated leaves were on average 68% affected by the two diseases, plots treated with benomyl and three rust sprays were 16% and 19% affected for propiconazole and maneb/mancozeb respectively. The effect of the rust control methods on yield is shown in Table 8 indicating the potential damage by this disease. (Lapwood with McEwen and Yeoman, Field Experiments Section)

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Potato diseases

Epidemiology of tuber diseases

***Powdery scab* (Spongospora subterranea).** Because increased amounts of powdery scab, especially of the disfiguring canker form, have caused concern in recent seasons, experimental work on the disease began in 1982. Diseased seed tubers (cv. Pentland Javelin) were planted in plots of an experiment with four different irrigation regimes at Gleadthorpe Experimental Husbandry Farm to explore the possibility that irrigation designed for common scab control would increase disease incidence. Irrigation treatments were: (1) none; (2) 12 mm water applied whenever the calculated soil moisture deficit (SMD) reached 18 mm during the 6 weeks after tuber initiation and thereafter 25 mm applied at 35 mm SMD; (3) 25 mm water applied at 35 mm SMD from early July onwards; (4) 30 mm water applied at 45 mm SMD from early July onwards.

There was a little powdery scab on tubers from all treatments (mean 11% tubers infected; 1·2% surface area affected) and no significant differences between them. This result is in contrast to Australian reports that early irrigation increases powdery scab. (Adams and Lapwood with Gleadthorpe EHF)

Silver scurf. Conidia of *Helminthosporium solani* on seed tubers in soil infect developing progeny tubers. To test when tubers are susceptible to infection conidial suspensions were watered on to plants 4, 6, 8, 10 and 12 weeks after planting. At harvest and after storage incidence of silver scurf was similar on tubers from plants untreated or inoculated up to 8 weeks after planting but more prevalent following inoculation after 10 or 12 weeks. This could explain why severely affected seed tubers, on which conidia would develop soon after planting, produce tubers with less silver scurf than tubers from slightly affected seed, which may produce conidia during a longer period if the lesions extend over the seed tuber surface. (Read and Hide)

***Gangrene* (Phoma exigua *var.* foveata).** The effect of storage temperature (in the range 2·5–20°C) on disease incidence was investigated in a series of experiments using various cultivars in several years. Disease incidence was greatest at the lowest temperatures. Analysis of the data after logit transformation showed that temperature significantly affected disease incidence in all experiments and there was usually no significant interaction between temperature and the other factors studied (e.g. relative humidity, wound type, inoculum concentration). Plots of disease incidence (logits) against temperature gave a series of straight lines of negative slope. To check whether there was a consistent relationship the means from each experiment were weighted according to their standard errors and subjected to a combined regression analysis. This showed that the data were well represented by a series of parallel lines of slope −0·151 (SE 0·0093), accounting for 91·4% of the total variance. A series of lines of different slopes did not account for a significantly greater proportion of the variance. Thus, within an experiment, disease incidence (x%) at different temperatures (t_1 and t_2) could be related by the equation:

$$\text{logit}\, x_{t_2} = \text{logit}\, x_{t_1} - 0{\cdot}151\,(t_2 - t_1)$$

(Adams)

Effects of fertilizer treatments on wound healing and gangrene susceptibility. The effects of various fertilizer treatments on the rate of wound healing and susceptibility to gangrene and to tuber damage were investigated in Maris Piper and Pentland Crown. The resistance to water loss of potato tuber discs healed for periods of up to 14 days at

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15°C 95% r.h. provided a measure of wound healing. Susceptibility to damage was assessed by a 'falling bolt' test and susceptibility of wounded tubers to gangrene infection was assessed in tubers 'cured' for 0, 3, 7 and 14 days at 15°C after inoculation. Tubers grown with increased rates of fertilizer e.g. 150% standard farm practice, were more susceptible to damage but healed wounds more quickly and were less susceptible to gangrene than those grown with the standard rate (1506 kg 13:13:30 plus 91 kg Mg ha^{-1}). (Marriott with Potato Marketing Board, Sutton Bridge)

Control of storage diseases with fungicides

Gangrene. Control of gangrene was investigated by immersing uniformly-wounded tubers in suspensions of thiabendazole (0·02, and 0·2% a.i.), 2-aminobutane (0·03 and 0·3% a.i.) or mixtures of both at the low and the high concentrations either immediately or after 3, 7 or 14 days at 5 or 15°C, before storage at 5°C for 12 weeks. At the low concentration thiabendazole gave better control of disease than 2-aminobutane on tubers held at 5°C for 3 days before treatment whereas at the high concentration 2-aminobutane was better when treatment was applied after 14 days (5°C) or 3 days (15°C). At both concentrations mixtures of both materials gave better control than thiabendazole alone when treatment was delayed and better than 2-aminobutane on tubers held at 5°C before treatment. It is probable that, unlike thiabendazole, 2-aminobutane penetrates into tuber tissues and thereby gives improved control of the disease when treatment is delayed.

Uniformly-wounded tubers treated for 1 min in suspensions of chlorpropham (0·01% a.i.) or dichlorophen (0·15% a.i.) were dried, immersed in a spore suspension of *Phoma exigua* var. *foveata* and treated with thiabendazole (0·1% a.i. suspension) either immediately or after 3, 7 or 14 days at 5 or 15°C before storage at 5°C. Treating tubers with dichlorophen but not chlorpropham increased gangrene and especially on tubers subsequently cured for 14 days at 15°C. Thiabendazole decreased the disease by similar proportions on pre-treated and untreated tubers.

To test effects of soil adhering to tubers on control of gangrene with thiabendazole, tubers were immersed in slurries made from soils with pH 4·6, 5·1 or 7·2, collected from plots on Sawyers 1 (Long Term Liming experiment) mixed with mycelial macerate of *P. exigua* var. *foveata* cultures at two concentrations, one ten times higher than the other. The following day tubers were uniformly wounded and sprayed with thiabendazole at 8 or 40 g a.i. t^{-1}. With dilute inoculum fewer rots developed on untreated tubers coated with soils of pH 7·2 than 6·1 or 4·6. At both concentrations of thiabendazole gangrene was controlled better on tubers with adhering soil of pH 7·2 than lower in comparison with non-fungicidally-treated tubers at the same soil pH, indicating that efficacy of thiabendazole may be decreased if tubers bear acid rather than neutral soil.

Dry rot. The effect of delaying fungicide treatment for control of dry rot was investigated by immersing Ulster Sceptre tubers in soil slurries containing *Fusarium solani* var. *coeruleum* or *F. sulphureum*. After uniform wounding tubers were dipped for 5 min in suspensions of thiabendazole or prochloraz at 0·01 or 0·1% a.i. either immediately or after 3, 7, 14 or 21 days at 5, 10 or 15°C before storage at 10°C for 8 weeks. With both pathogens incidence of dry rot on untreated tubers was not affected by holding tubers for up to 21 days at 5°C and increased by holding them for 7–21 days at 15°C before storage at 10°C; this contrasts with the effects of curing temperature on gangrene which was greatly decreased by curing for 14 days at 15 compared with 5°C. (*Rothamsted Report for 1981*, Part 1, 203). Fungicide treatment (means over both materials and concentrations) immediately after wounding prevented rots on almost all wounds (3%

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infected) whereas when treatment was delayed for 3 days, 27 (5°C), 37 (10°C) or 38 (15°C) wounds were infected. Rots developed at increasing numbers of wounds with increasing interval between wounding and treating, especially on tubers held at 15°C which developed rots at 60% of wounds following treatment after 21 days.

Skin spot. Effects of delaying fungicide treatment on skin spot were also tested. Tubers were given 50 pin pricks immersed in a spore and mycelial suspension of *Polyscytalum pustulans*, subsequently held in either dry or moist conditions at 5, 10 or 15°C and dipped for 5 min in suspensions of carbendazim (0·001, 0·01, 0·1% a.i.) after 1, 4, 7, 14 or 21 days before storage in sealed polyethylene bags at 5°C for 24 weeks. On untreated tubers stored moist skin spot decreased slightly with increase in temperature during the holding period but was not affected by its duration, whereas with tubers held dry it was greatly decreased by increase in temperature and also by increasing the interval between inoculation and storage at 5°C. No skin spots developed on tubers stored dry for 21 days at 15°C whereas they developed at 80% of wounds on tubers stored at 5°C immediately after inoculation.

Incidence of skin spot increased when fungicide treatment of moist-stored tubers was delayed for up to 21 days and especially after holding at 15°C. Treatment after 4 days at 15°C gave least disease and less than treatment 1 day after inoculation. Similarly, fungicide treatment of tubers stored dry for 4 days at 15°C gave less disease than treatment after 1 day but was effective even after 21 days at 5°C. These results suggest that curing tubers in dry conditions can control skin spot but not when moist and that if they are stored moist treatment is most effective when applied 4 days after infection whereas with dry tubers efficacy increases as treatment is delayed. (Hide and Cayley)

Blackleg (*Erwinia carotovora* subsp. *atroseptica*)

Effect of blackleg on yield and compensation. In field experiments in 1981 and 1982 the effect of inoculating seed tubers with *Erwinia carotovora* subsp. *atroseptica* immediately before planting on subsequent symptoms, yield and ability of the plants to compensate for weak or missing neighbours was investigated. Single row plots of cv. Désirée were planted with tubers that were uninoculated (UI), inoculated at the heel end (HI) or inoculated at the rose end (RI) either at normal (15 in) or at double spacing. In other plots, HI or RI tubers were planted alternately with UI.

Inoculation decreased mean stem height and (RI only) stem numbers per plant: symptoms of blackleg sometimes developed, especially with RI. At the end of the season individual plant yields were recorded. Results were similar in the 2 years. Those from 1982 (Table 9) showed that in plots of uniform seed type at normal spacing, inoculation decreased total yield to 87% (HI) and 60% (RI) of the yield from UI tubers. At double spacing yields were 158% (UI), 155% (HI) and 130% (RI) of normally spaced plants showing that diseased plants were less able to compensate for missing neighbours. When RI and UI tubers were planted alternately, the inoculated plants yielded 77% and the uninoculated ones 124% of those from plots planted throughout with RI tubers. No such effect occurred in HI plants. Tuber numbers per plant were decreased by about 50% with RI but were not usually affected by spacing differences. (Adams and Lapwood)

Blackleg susceptibility. Ways of assessing the field susceptibility of cultivars to blackleg (*Erwinia carotovora* subsp. *atroseptica*) have been sought in collaborative experiments with the National Institute of Agricultural Botany, Cambridge, since 1980, when it was decided that blackleg susceptibility should be added to the list of diseases assessed for the NIAB Farmers Leaflet No. 3, *Recommended varieties of potatoes*.

Seed tubers stab-inoculated at the heel end just before planting at Cambridge in plots

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TABLE 9

The effect of seed tuber inoculation with Erwinia carotovora *subsp.* atroseptica *and of adjacent plant treatment on yield of potatoes, cv. Désirée (kg per plant)*

Inoculation treatment	Adjacent plant: Uninoculated	Heel inoculated	Rose inoculated	Missing
None	1·67	1·67	2·07	2·65
Heel end	1·48	1·45	—	2·25
Rose end	0·77	—	1·00	1·30

SED 0·118 (45 d.f.)

— not included

irrigated from emergence to maintain low moisture tensions, have successfully reproduced symptoms of the disease (see *Rothamsted Report for 1969*, Part 1, 170). Following limited field observations, an attempt was made in 1982 to assess in greater detail the damage done to plants of six cultivars. Estima was the most seriously affected: 20% failed to emerge and those plants that did had fewer stems than water-inoculated controls, many showed blackleg symptoms, and yield was decreased by 70%. Most Maris Bard plants emerged but were severely damaged by disease and yield was decreased by 27%. Fewer plants of Cara, Wilja and King Edward showed blackleg and gave respectively 25, 20 and 10% less yield than controls. Pentland Crown although showing little sign of disease nevertheless suffered an 18% yield reduction. (Lapwood with Gans and Ramsbottom, NIAB Cambridge)

Control of potato virus Y (PVY). Many *Myzus persicae* on leaves treated in the laboratory with the organophosphorus insecticide demeton-S-methyl secreted alarm pheromone before dying; nymphs tended to secrete sooner, stimulating the dispersal of nearby adults. Disloged adults were often capable of walking at least 120 mm and about 10% of those from PVY-infected leaves infected tobacco test plants. Despite this relatively low rate of transmission, the insecticide-initiated dispersal of aphids could be responsible for considerable spread of PVY and we believe it is important to discover how extensive this phenomenon is in crops.

Although in parallel tests the pyrethroid deltamethrin did not induce alarm pheromone release, at 0·001% a.i. moderately-pyrethroid-resistant alates flew in greater numbers from deltamethrin-treated than from untreated leaves within 5 min of contact; a greater dose or longer exposure was required to induce flight of strongly-resistant alates. Flight was probably due to the excitatory effect of the pyrethroid. However, most aphids which flew from treated, infected leaves became intoxicated soon after leaving and few transmitted PVY when transferred to healthy test plants. Furthermore, in the field, sprays of deltamethrin (12·5 g a.i. ha^{-1}) at monthly intervals diminished the incidence of potato plants bearing PVY-infected tubers by 15%, and six fortnightly sprays with cypermethrin (37·5 g a.i. ha^{-1}) diminished the numbers of plants showing primary symptoms by 80% (results for tuber infection are not yet available).

Laboratory tests of the abilities of aphid alarm pheromone derivatives (see Insecticides and Fungicides Department, pp. 126–127) to affect transmission of PVY showed that the tetradecyl straight-chain, fully-saturated derivative was especially active, a 0·1% aqueous emulsion diminishing acquisition by *M. persicae* by 30–50%. (Gibson with Dawson, Pickett and Rice, Insecticides and Fungicides Department)

Potato virus diseases at Rothamsted. When counts were made in mid-June, plots planted with King Edward seed grown at Rothamsted in 1981 had 0·3% infection with

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potato virus Y (PVY) but no potato leaf roll. Pentland Crown and Désirée were not infected with either virus. Aphids (*Myzus persicae*) were scarce in June when potato plants are at their most susceptible and at the end of July no current-season infection was detected in crops for 1983 seed, although some current-season spread had occurred in plots planted with Rothamsted once-grown seed. (Govier)

Overseas co-operation

A new virus disease infecting watermelon in the Peoples Democratic Republic of Yemen. A disease of watermelons causing a severe blistering and malformation of fruits, yellowing and necrosis of leaves has been shown to be associated with a 28 nm isometric virus particle. The virus occurs in high titres (10^7) in the leaf tissue and in the electron microscope is morphologically similar to viruses of the turnip yellow mosaic virus group (tymoviruses). The virus has a single protein of molecular weight 20 000 and sediments ($S_{20,w}$) as two components of 117S and 68S, characteristics typical of tymoviruses. Although isolated from cucurbits our virus could not be mechanically transmitted to a range of cucurbit and local lesion test plants. No serological relationships could be detected in gel diffusion tests between this virus and other tymoviruses including turnip yellow mosaic virus, Andean potato latent virus, wild cucumber mosaic virus and dulcamara mottle virus. The virus causes considerable damage to watermelon crops in Yemen. (Jones and Carpenter)

Sumatra disease of cloves. Immunofluorescent antibody tests have been used to examine the relationship between the Sumatra disease organism (*Rothamsted Report for 1979*, Part 1, 170) and other gram-negative xylem-limited plant pathogenic bacteria. The clove organism is related to similar bacteria causing diseases of the Californian buckeye tree and a wilt of 'Toronto' creeping bentgrass, revealing at least two serogroups of these plant pathogens. The response of the clove organism to a range of antibiotics has been determined: those which affect protein synthesis are the most effective bacterial growth inhibitors. A selective isolation medium for use in the field is under development. (Jones)

Staff and visiting workers

The following staff changes occurred during the year: O. C. Cronshaw retired, S. Forde transferred from glasshouse to laboratory duties and R. D. Prew transferred to Field Experiments Section. Following these changes and the retirement of G. A. Salt in November 1981, Derek Shaw, Richard Thorne and Mrs Maureen Lacey (part-time) were appointed to ASO posts, thus to some extent redressing the imbalance in the senior research : support staff ratio in the Department.

E. Lester was elected Chairman of The British Crop Protection Council for a second 2-year term, was appointed Chairman of the Organizing Committee for the 10th International Congress of Plant Protection to be held in the UK in 1983, and nominated President-Elect of the newly-formed British Society for Plant Pathology. C. J. Rawlinson, who was active in the creation of the new Society, became its first Secretary.

The Department was host to members of the National Association of Seed Potato Merchants for their winter and summer training visits, organized by M. J. Adams. J. F. Jenkyn and R. T. Plumb organized a well-attended and successful 3-day EEC Workshop on Diseases of Legumes, in May.

K. D. Delaney, thesis entitled 'Root-infecting fungi of grain and forage legumes' and N. Magan, a United Nations Fellow, thesis entitled 'Studies on the microflora of wheat grain: Ecology of the fungi and effects of fungicides' were each awarded the Ph.D. degree of Reading University, while A. Swaby gained a B.Sc. degree in Biology following part-

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time study at the Luton College of Higher Education. P. T. Gans, who was a student in the Department from 1974 to 1978, was awarded a M.Phil. degree from the University of London, thesis entitled 'Biochemical aspects of resistance of potato tubers to gangrene'.

S. J. Eden-Green, A. J. Dabek, P. Hunt and C. P. Bennett all spent writing-up periods in the Department with ODA support and S. J. Eden-Green joined the ODA Sumatra Clove Disease Scheme with P. Hunt in June.

Visiting scientists who stayed for periods less than three months included C. R. Fisher (Zimbabwe) aerobiology techniques; Dr Sami Freigoun (Sudan) *Vicia* bean diseases; and U.N.O. Palmgren and G. Ström (Sweden) identification of Actinomycetes.

Maryse Chabrol (France) continued her studies on the effects of soil sterilants on the growth of maize. N. Katis (Greece) continued his investigation of potato virus Y transmission and Susan Marriott (CASE Student with the Potato Marketing Board) came towards the end of her investigation of wound-healing in relation to disease. P. H. Flavelle and Penelope Shaw were sandwich course students, while Christina Cox, L. Nicolas (France) and J. van Bilsen (Holland) were self-supporting voluntary workers. Miss Flores Griffith (St Lucia) was a post-graduate student on an M.Sc. course at Reading University, assisting investigations on potato stem canker.

P. H. Gregory continued to work in the Department at the invitation of the Lawes Agricultural Trust. Dr B. P. R. Vittal (aerobiology of plant pathogens) returned to India at the end of January and Mr M. Ivanović (soil-borne fungal vectors of viruses) extended his stay on a self-supporting basis and returned to Yugoslavia in August. G. V. Dyke (Field Experiments Section retired) joined the Department on a temporary basis to continue his collaboration with J. F. Jenkyn.

A. Bainbridge and B. D. L. Fitt attended an EPPO/WMO meeting in Geneva on 'Meteorology for Plant Protection'. R. W. Gibson visited the International Potato Centre, Peru, in March to chair a Conference Session and give a paper, and also gave papers during discussion visits to the Netherlands and Belgium in November. P. Jones attended the 2nd International Maize Virus Disease Workshop and Colloquium, Wooster Ohio and paid visits to the Universities of Florida and Georgia in July/August. R. H. Turner attended an International Electronmicroscope Conference in Los Angeles to give a paper in April/May.

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