ROTHAMSTED RESEARCH

Report for 1978 - Part 1

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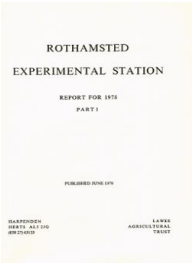

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Introduction

After a favourable autumn sowing time in 1977 most winter cereals grew well and winter barleys already supported substantial levels of mildew before the winter. In sowing date experiments, later sowings fared less well, producing gappy, slow-growing crops which, however, emerged from the winter virtually mildew-free; the disease became prevalent in early summer but severe only on late-sown crops. On spring sowings, mildew was slow to develop, probably inhibited by a spell of hot dry weather towards the end of May, but became moderate to severe during June. Brown rust became more severe than is usual at Rothamsted, associated with long-delayed maturation of the spring barley, a feature not restricted to this crop. The season generally favoured spread of splash-borne diseases, a fact reflected in some of the reports that follow.

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Potato diseases associated with dull wet weather were also in evidence until towards September when drier weather slowed blight development on unsprayed crops. Spraying contained the epidemic well and the onset of drier weather which enabled rapid harvesting also virtually eliminated tuber infection. Wetter conditions encouraged the spread in potatoes of soft-rotting *Erwinia carotovora*; var. *atroseptica* more than var. *carotovora* and more from stem lesions than from tubers in soil (p. 222). Some effort has been devoted to the problem of chemical control of bacterial rotting and discrepancies in the relative effectiveness of bactericides *in vivo* and *in vitro* have been revealed (p. 223).

Survival of the gangrene pathogen in soils in controlled experiments done annually for the last 4 years indicates that soil is unlikely to be important as a source of inoculum for potatoes in normal rotations (p. 223). Our investigations of the epidemiological significance of stem lesions caused by *Phoma exigua* var. *foveata* have shown that stem infection can occur from contaminated soil as well as from infected parent tubers, but without producing symptoms until after the haulm dies. However, removal of haulm before lesion development failed to decrease tuber infection (p. 224). Many aspects of gangrene epidemiology remain as yet obscure.

Investigations into the use of fungicides for tuber disease control have shown useful effects on some diseases in large-scale experiments on commercial farms (p. 225) but not commensurate with the results in controlled experiments at Rothamsted. In a season in which stem canker was common and severe, treating seed tubers, sprouts, or the planting furrow with fungicides proved very effective in disease control and increased total yield by up to 40% in one trial (p. 225). The search for more effective fungicides and methods of application continues actively, in collaboration with Chemical Liaison Unit (p. 225).

The seasonal variation in cereal aphid numbers and the proportion carrying barley yellow dwarf virus is emphasised by the 1978 results (p. 210) which lead us to suggest that early autumn sown cereals may be extensively infected even though only a small proportion of migrating aphids was infective. Although substantial increases in yield of winter barley have been recorded following autumn sprays for mildew control, the large coefficients of variation which seem to be characteristic of our winter-barley experiments have rendered the increases – up to 7%, non-significant (p. 211). The complexity of the relationships between season, sowing date and disease control is well exemplified by results of experiments on spring barley in 1977 and 1978, seasons that produced almost opposite results in terms of response to treatment (p. 212). The results last year of experiments on the effects of herbicides on overwintering of *Rhynchosporium secalis* have been broadly confirmed and the effects of fungicides shown to be variable, one material having apparently enhanced spore production (p. 212).

The complicated taxonomy of the fungi associated with take-all disease is not simplified by the discovery of another, as yet unidentified *Phialophora* sp., which must cast even more doubt upon the validity of visual diagnosis of take-all (p. 213). Further studies of take-all distribution in relation to cultivations confirmed earlier results showing a concentration of infected roots in the upper soil layers in direct-drilled plots. This pattern was consistent by July irrespective of cultivation method, indicating that our normal hand-pulling sampling technique is satisfactory for such comparisons (p. 214). Our prediction that take-all would be common in second wheats in 1978 was borne out in practice. This was based in part on soil assays, measuring inoculum build-up and this now seems to be confirmed as a useful research tool. Its value in forecasting take-all is limited, however; it is very laborious and in any case measures only inoculum, while the disease is very weather dependent (p. 215). As part of our programme on splash-borne diseases, investigations on the epidemiology of eyespot disease of cereals started in the autumn of 1977 and it has soon become clear that better spore trapping techniques are required if good progress is to be made. Nevertheless, we have shown that eyespot spores were avail-

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able virtually throughout the growing season and infection of trap-plants occurred every week from November to June (p. 215).

As a necessary pre-requisite for screening clovers for susceptibility to clover rot, we are now able to produce sclerotia, and subsequently fertile apothecia reliably and reproducibly in an artificial system (p. 217). Further outbreaks of red clover necrotic mosaic have been confirmed, indicating its probable widespread distribution in Britain. Transmission experiments encourage the supposition of a fungal vector but this remains to be proven. The probability of mechanical transmission during cutting has been demonstrated (p. 218). What appears to be a different sort of resistance to ryegrass mosaic virus than that previously reported has been discovered in the perennial ryegrass cultivar Endura. Its value has yet to be assessed (p. 218).

Attempts to control the root-rot complex of autumn-sown lupins (p. 218) and of spring-sown field beans (p. 220) by chemicals were unsuccessful. However, emergence and survival of both autumn and spring-sown lupins were improved by some fungicide combinations. Viruses isolated from lupins have been identified as bean yellow mosaic virus (two isolates) and clover yellow vein virus (one isolate) (p. 219). In an experiment to control chocolate spot of winter beans, irrigation decreased yield without affecting chocolate spot severity and benomyl sprays decreased disease and increased yield progressively (up to four sprays) to *c.* 6 t ha^{-1} (p. 220). The presence of vicia cryptic virus in a high proportion of some cultivars of field bean has been confirmed but attempts to transmit the virus other than through seed have so far failed. Particles of similar shape and size have been found in apparently normal alsike clover and lucerne plants (p. 220).

Attempts to control light leafspot and canker of oilseed rape with fungicides met with some success and resulted in yield increases in a year of relatively severe disease (p. 221).

In virus inactivation studies, acetyl salicylic acid and some other small molecular weight acids have been shown to inhibit TMV multiplication and to induce b proteins more effectively and in more tobacco cultivars, than polyacrylic acid, when injected, sprayed, or watered on to soil in which the plants were growing (p. 207). Inhibition of TMV in protoplasts by the phytolacca inhibitor can be achieved with as little as 1 h exposure to inhibitor. It is suggested that physical damage to protoplasts may be involved (p. 208). Attempts to develop the ELISA test for diagnosis of BYDV have been successful with some, but not all, English isolates tested, and in some tests using infected aphids as antigen (p. 211). Purification studies of rice tungro viruses have been hampered because the viruses reach only a very low concentration at Rothamsted, where the vector has been reared and used in transmission tests successfully (p. 208).

The effectiveness of propionic acid as a hay preservative is limited by the ability of certain moulds to metabolise it. All the *Aspergillus glaucus* group commonly found in hay have been shown to have this ability but to different degrees and *in vitro* methods for assessing this ability have been developed. A range of chemicals has been tested in attempts to improve preservation, some of which held some promise (p. 208). In trials, the microflora of wheat grain was modified by fungicides applied to the crop; bacteria tended to be more numerous, yields were increased and germination and seedling growth improved. Milling and baking quality were not affected significantly by treatments (p. 209).

Properties of viruses and virus diseases

Induction of resistance to tobacco mosaic virus (TMV) in tobacco by acetyl salicylic acid. Leaves of tobacco, *Nicotiana tabacum* cv. Xanthi-nc became completely resistant to infection with TMV 4–7 days after injecting the leaves with a 0·02% solution of acetyl salicylic acid, pH 6·5. As leaves became resistant three new proteins appeared, seemingly identical to those produced following injection with polyacrylic acid which also induces

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resistance to TMV in this variety of tobacco (*Rothamsted Report for 1974*, Part 1, 117). Although both acetyl salicylic acid and polyacrylic acid induce resistance when applied to the plant as a spray or by watering the soil, acetyl salicylic acid is effective at lower concentrations than polyacrylic acid. Polyacrylic acid does not induce resistance or formation of new proteins when injected into the Samsun NN and White Burley varieties of tobacco. However, acetyl salicylic acid induces both resistance and associated new protein formation in these varieties. A 0·01 % solution of salicylic acid or a 0·1 % solution of benzoic acid also induces resistance to TMV and the formation of new proteins when injected into these tobacco varieties. (R. F. White)

Effects of the phytolacca inhibitor on TMV multiplication in tobacco protoplasts. The virus inhibitor extracted from plants of *Phytolacca americana* L. by the method of Grasso and Shepherd (*Phytopathology* **68,** 799–805) was added to tobacco protoplasts previously inoculated with TMV. When added immediately after infection a concentration of inhibitor above 10 μg ml^{-1} almost completely inhibited virus multiplication after 48 h even when the duration of treatment was as short as 1 h. The viability of protoplasts following treatment was determined by staining with methylene blue. At a concentration of 10 μg ml^{-1}, no virus was produced 48 h after treatment and the protoplasts were able to reduce the dye; at a concentration of 100 μg ml^{-1} the inhibitor killed the protoplasts. Virus multiplication was considerably reduced when the inhibitor was added up to 6 h after inoculating the protoplasts but not after 24 h. The inhibition could be prevented by adding 40 mM $CaCl_2$ to the protoplast incubation medium and is in this respect similar to the inhibition caused by rabbit serum (*Rothamsted Report for 1976*, Part 1, 251). Protoplasts treated with inhibitor for 48 h and able to reduce methylene blue, were examined in thin section in the electron microscope. Compared with untreated controls, the treated protoplast membranes were disrupted, cytoplasm had been leached out and the chloroplast thylakoids were severely swollen. It seems probable that although appearing in good condition as indicated by ability to reduce the dye, the protoplasts had been damaged by the inhibitor to such an extent that they were unable to allow multiplication of TMV. (Jones, R. F. White, Woods and Dr. S. Grasso, Instituto di Patologia Vegetale, Catania)

Rice tungro viruses. Tungro disease of rice is seemingly caused by a dual infection with a spherical and a bacilliform virus. At Rothamsted the vector *Nephotettix viriscens* transmitted both viruses simultaneously from infected to healthy Taichung Native – 1 (TN-1) rice plants but in tests with Sigadis and M1-48 rice varieties, some plants were infected with only one or other of the viruses, as judged by electron microscopy of sap. TN-1 rice infected with tungro disease by Dr. K. C. Ling at the International Rice Research Institute, Philippines, was brought to Rothamsted and stored frozen. Partially purified virus preparations made from this material contained numerous spherical (*c.* 30 nm diameter) and bacilliform particles. The length of the latter was very variable (70–240 nm) and length distribution plots did not indicate the presence of any major components. All the particles were 25–35 nm wide. However, the tungro viruses reached a much lower concentration at Rothamsted than at IRRI and this makes it difficult to grow sufficient infected rice here for virus purification studies. (Kenten)

Biodeterioration

Chemical preservation of damp hay. Hay stored damp develops a succession of micro-organisms, initially mostly fungi; and heats spontaneously as a result of their respiration. Moulding in bales can be prevented by treatment with 1–2 g of propionic acid 100 g^{-1} hay (or the acid part-neutralised with ammonia) but in practice it often spreads from

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small foci through the bulk of treated hay (*Rothamsted Report for 1977*, Part 1, 157). The fungi initially colonising the treated hay are succeeded by others less tolerant of propionic acid indicating that the chemical has been metabolised. *Paecilomyces varioti* and all species of the *Aspergillus glaucus* group usually found in hay have been identified among the initial colonisers and all are able to metabolise propionic acid, though isolates vary in the concentration they can tolerate.

Methods for growing these organisms on liquid media have been developed and used to assess their ability to metabolise propionic and other fatty acids. Isolates of both *P. varioti* and *A. glaucus* group could tolerate and metabolise concentrations of propionic acid in culture media up to a maximum of about 10 000 ppm, which inhibited other fungi found in moulding hay; and also other fatty acids. Uniform application of preservative is needed to avoid degradation of propionic acid by fungi colonising and spreading from undertreated pockets. In field experiments, species of the *A. glaucus* group most frequently initiate moulding.

In attempts to improve chemical preservation of moist hay we tested other substances alone and in combination with propionic acid. Chemicals which prevented moulding when added at 0·5% w/w to hay containing 30% water included sorbic acid, phenol and some substituted phenols, 8-hydroxyquinoline, formaldehyde, propionaldehyde and various aliphatic acids. Some longer chain fatty acids and aldehydes and phenyl mercuric acetate only delayed moulding, while many commercial fungicides, aliphatic alcohols and amines had no effect. Propionic acid alone, at 0·2 g 100 g^{-1} hay did not prevent moulding but did so when 0·02 g formaldehyde, zineb, phenyl mercuric acetate, 8-hydroxyquinoline or some halogenated or nitro derivatives was added.

In vitro tests on isolated fungi showed that as little as 10 ppm 8-hydroxyquinoline and its derivatives in the medium could inhibit the degradation of aliphatic acids. These substances however are strongly sorbed on hay so that much larger quantities are needed in hay. Laboratory tests of differing mixtures of 8-hydroxyquinoline and propionic acid, either as the free acid or part neutralised with ammonia, showed that addition of 10 g 8-hydroxyquinoline per 100 g propionic acid halved the requirement for propionate to prevent moulding. When moulding of hay occurred in Dewar flasks the rate of spread was frequently slowed so that heating was diminished. The same proportion of 8-hydroxyquinoline in propionic acid improved the control of moulding of other stored crops such as wheat, oats, barley, rape and beans.

Field scale trials with a formulation of one part 8-hydroxyquinoline and ten parts propionic acid then half neutralised with ammonia, containing *c.* 70 g propionic acid 100 g^{-1}, showed promise in preventing moulding. Used on late-cut grass in a dry season, the formulation decreased the amount of propionic acid required to prevent moulding to one quarter that of the acid alone: however, used on lucerne hay or on a slow-drying leafy crop of grass cut early the requirement was only halved. In both tests, species of the *Aspergillus glaucus* group appeared most tolerant of preservative treatment. (Lacey with Lord, Cayley and Manlove, Chemical Liaison Unit)

Microflora of grain during ripening. As in previous years (*Rothamsted Report for 1977*, Part 1, 211), micro-organisms on newly emerged ears of winter-sown wheat (cv. Maris Freeman) were few ($< 1{\cdot}4 \times 10^6$ propagules g^{-1}) but increased rapidly during development and ripening. Bacteria and yeasts were most abundant at the watery ripe stage (respectively 400×10^6 and 11×10^6 propagules g^{-1}) but other fungi continued to increase until near harvest when 15×10^6 propagules g^{-1} were found. *Hyalodendron*, *Verticillium*, *Aureobasidium*, *Cladosporium* and *Alternaria* were isolated most frequently. Spring-sown wheat (cv. Sappo) was colonised similarly but bacteria were fewer and yeasts more abundant than on the winter-sown.

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The microflora of both winter- and spring-sown wheats was modified by fungicides applied once, twice or three times in all combinations, near growth stages (GS) 60, 70, and 80. Single sprays of captafol decreased yeasts and other fungi by 90% within 24 h of spraying but numbers had recovered to 50% of control plots 8 days later. Benomyl and 'Delsene M' (carbendazim + maneb) appeared slower acting with numbers of fungi smaller 9 days after spraying than 1 day. Approximately 3 weeks after the last spray, captafol and benomyl treated plots of winter wheat sprayed three times had fungal populations 30% less than controls but benomyl decreased yeasts and bacteria less than captafol. By contrast, populations of fungi and bacteria on plots receiving three sprays of 'Delsene M' differed little from the controls except that yeasts were 43% more numerous. Differences were less apparent after harvest although, in general, numbers of fungi were smaller on captafol-sprayed grain while yeasts and bacteria were more numerous on all fungicide-treated grain, especially from the spring-sown crop.

Yields of grain were increased by all fungicides. The mean yield of all 'Delsene M'-treated plots of Sappo was increased by more than 5% while all other fungicide treatments of both winter- and spring-sown crops averaged 3% increase with individual treatments up to 10%. Although earlier sprays (GS 65–71) tended to give bigger increases there was no consistent effect of spray timing. Fungicides also improved seed germination and seedling growth.

Lodging of spring wheat increased the incidence of *Fusarium* on grain and decreased *Alternaria*, yield, germination and shoot growth. Irrigation further increased *Fusarium* on lodged plots but despite the occurrence of up to 5% grains with *Fusarium*, no toxins could be extracted. As in 1977, chlormequat chloride improved yield and germination of grain but decreased subsequent seedling growth. *Alternaria* was also slightly decreased. (Lacey and Rosemary Gutteridge)

Isolates of *Alternaria* from ripening wheat ears grown on sterilised grain produced the metabolites alternariol, alternuene and alternariol monomethyl ether. (Lacey and Unsworth)

Milling and baking tests on grain from spring-sown wheat (cv. Sappo) harvested in 1977, carried out by the Flour Milling and Baking Research Association, showed few differences between fungicide-treated and control plots. Loaf scores were similar for all treatments and close to the average score for bread from English wheat flours. Specific weights, flour yields, protein contents and Hagberg numbers of fungicide-treated wheats were slightly greater than from control plots but not significantly so. (Hill)

Cereal diseases

Barley yellow dwarf virus (BYDV)

Infective aphids. In 1977 the time of occurrence of infective aphids was similar to previous years, as the first infective aphid was *Rhopalosiphum padi* caught on 24 May, followed by *Macrosiphum* (Sitobion) *avenae* on 16 June and *Metapolophium dirhodum* on 4 July: 4·8% of *R. padi*, 4·7% of *M.* (*S.*) *avenae* and 3·8% of *M. dirhodum* transmitted BYDV to test plants but as *R. padi* was much more numerous than for many years it was the commonest vector.

By contrast, in 1978 few cereal aphids were caught in spring and summer and none was infective until 17 July when single specimens of *M.* (*S.*) *avenae*, *M. dirhodum* and *M. festucae* each transmitted BYDV to test plants. *R. padi* were not trapped until 25 September but then became numerous. Fortunately only 3% of this autumn migration was infective, nevertheless there is a risk that early sown cereals may be extensively infected. (Lennon and Plumb)

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Winter cereals. As the infectivity trap catches indicated, aphids and infection by BYDV were rare on all cereals in 1978. However, phorate applied to the seed-bed significantly increased (6·94 to 7·65 t ha^{-1}) the yield of wheat cv. Flanders sown on 6 October 1977 but had no effect on crops sown on 4 and 25 November. This increase in yield could not apparently be accounted for by differences in aphid and virus incidence. In a similar experiment on oats cv. Peniarth, phorate again increased yield most on the earliest sown plots but the increases were not significant. (Lennon and Plumb)

BYDV and enzyme-linked immunosorbent assay (ELISA). An antiserum prepared in New Zealand to an isolate of BYDV transmissible by *R. padi* reacted in ELISA tests with both roots and leaves (0·2 g samples) of oats infected by an isolate of BYDV originating in England and with *R. padi* as its most efficient vector, but did not react with an isolate most efficiently transmitted by *M.* (*S.*) *avenae*. A reaction was also detected when a large number of *R. padi* that had fed for several days on infected plants were used as the antigen. As a preliminary step before purifying British isolates of BYDV a range of host plants was tested to determine their relative virus concentrations. Samples were taken 3, 4, 5 and 6 weeks after inoculation. BYDV concentration was generally greater in roots than leaves and in oats, wheat and barley than in maize, Italian and perennial ryegrasses, and timothy. In the C_3 cereals, virus concentration was greatest in oats and least in barley and these differences were more marked in leaves than roots. Virus concentration, with minor fluctuations, declined during the sampling period. (Lennon and Plumb, with Dr. M. F. Clark, East Malling Research Station)

Effects of new fungicides on fungal infections of cereal roots. A preliminary trial to test the effects of 'CGA. 48988' and 'LS 74783' ('Aliette') on root-infecting fungi was made with winter wheat, cv. Cappelle, grown in 10-cm diameter pots containing a mixture of equal parts of field soil and sand. 'CGA 48988' at 0·012 g a.i. and LS '74783' at 0·4 g a.i. per pot were applied in 100 ml water after emergence and the presence or absence of fungi was recorded 6 weeks later by direct microscopical examination of 30 × 1 cm root pieces from each of eight replicate pots. 'CGA 48988' and 'LS 74783' decreased the percent root-pieces infected with *Pythium* spp. from 8% in untreated controls to less than 1 and 0% respectively and with the mycorrhizal fungus *Endogone* from 30% to 4 and 9% respectively. Only 'LS 74783' decreased infection by *Lagenocystis*, from 10% in controls to 0%. Neither fungicide affected *Olpidium* (only 4% in controls) or *Gaeumannomyces graminis* (63% in controls). (Salt)

Powdery mildew (*Erysiphe graminis*) on winter barley. A factorial experiment tested tridemorph sprays in autumn and spring, seed rate, sowing date and time of applying nitrogen in spring for their effects on mildew development and crop yield. The variety Hoppel was sown at 78 or 156 kg ha^{-1} on 6 October and 2 November. Tridemorph was applied (at 700 ml a.i. ha^{-1}) on 18 November to plots in the early sown treatment only and on 3 May and 26 May to plots in both sowings. Nitrogen at 75 kg ha^{-1} was applied on 6 March or 25 April.

Seedling emergence in the early sown plots was relatively uniform and plants grew well reaching GS 21 by mid December. At this time older leaves of plants in unsprayed plots had 10% and in sprayed plots less than 2% leaf area affected by mildew. In late sown plots, seedling emergence was not uniform, there were many gaps in the rows and crop growth was uneven; by the end of the winter plants had only reached GS 12–13 but they were almost free from mildew infection. At the end of April the green leaf in both sowings was virtually free from mildew, which did not become prevalent again until early summer

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and then severe only in the late sown crop where, on 6 July in unsprayed plots, mildew on second leaves was 14% while on sprayed plots it was 2%.

The average yield of early and late sown plots was 5·56 and 3·60 t ha^{-1} respectively. Seed rate had no effect on yield. At the smaller seed rate, extra tillering (2·68 *v.* 1·76 tillers per plant), more grains per ear (42·3 *v.* 38·3) and larger grain size (41·0 g *v.* 39·7 g 1000-grain weight) compensated for the smaller number of plants (17 *v.* 30·7 m^{-1}) when compared with the early sowing. Nitrogen improved yield more when applied on 6 March to early-sown plots and on 25 April to late-sown plots, that is at GS 24 in each case.

Large coefficients of variation have been characteristic of our winter barley experiments (10·9% in this instance) so that, although the autumn application of tridemorph gave a 7% yield increase, when compared to unsprayed crop, this was not significant. Sprays applied at either date in May to early sown plots on average increased yields from 5·0 to 5·75 t ha^{-1}. Spraying twice gave no extra yield increase. Although sprays reduced the amount of mildew on late-sown plots they did not significantly increase yield. (Bainbridge, Finney and Jenkyn)

Diseases of spring barley. Mildew on spring barley at Rothamsted during May was generally only slight but the disease developed rapidly at the end of that month and, on susceptible varieties, had become moderate to severe by early June. In most crops, brown rust before the middle of July was only slight. Although it never became severe, unusually late maturity of cereal crops at Rothamsted allowed it to develop much more than we had expected.

Effects of sowing date. Experiments to investigate the interactions between sowing dates and pathogen control (*Rothamsted Report for 1976*, Part 1, 257) were continued in 1977 and 1978. In both years, late sowing resulted in increases in severity of mildew, numbers of aphids and incidence of BYDV. In 1977 (cv. Julia) fungicides (ethirimol to the seed plus tridemorph sprays) and phorate (to the seed-bed) each gave little or no benefit when applied to early-sown barley but much increased the yield of late-sown. Where neither fungicides nor phorate were applied, late-sown plots yielded 4% less than early-sown (5·47 and 5·73 t ha^{-1} respectively) but where both were applied they yielded 16% more (6·89 and 5·95 t ha^{-1} respectively). In 1978 (cv. Wing) aphids and virus infection were infrequent and application of aphicides had no significant effect on yield. On average, ethirimol applied to the seed increased yield by 4·4% (from 5·25 to 5·48 t ha^{-1}) but there was a significant interaction with sowing date. On early-sown barley it increased yield by 11·1% (from 5·50 to 6·14 t ha^{-1}) but on late-sown there was a decrease of 3·8% (from 5·01 to 4·82 t ha^{-1}). (Jenkyn and Plumb)

Observations on *Rhyncosporium secalis*

Effect of herbicides and fungicides on the number of spores on barley stubble and volunteers. Preliminary results of an experiment comparing the effects of glyphosate and paraquat on the number of spores washed from stubble and volunteers were given in the *Rothamsted Report for 1977*, Part 1, 214. Single sprays of the herbicides were applied to plots on 27 September or 18 October. Spore numbers on stubbles were monitored weekly for the 4 succeeding weeks and on volunteers for 9 weeks after spray 1 and 11 weeks after spray 2. (Table 1).

On 6 December 10·7 × 10^5 spores were washed from one hundred 20 cm lengths of paraquat-treated stubble (sprayed 27 September): 12·1% of the spores were found to be viable. Volunteers which had grown subsequent to the application of the herbicide

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TABLE 1

Spores cm^{-1} of stubble or × 10^{-3} per volunteer plant

		Untreated		Paraquat		Glyphosate	
	Weekly sample occasions	stubble	volunteer	stubble	volunteer	stubble	volunteer
Spray 1	4	702	5060	579	1350	665	930
	4		7430		67		130
	1		2730		9		18
Total as percentage of untreated				82·3	9·4	95·0	7·1
Spray 2	4	91	6090	102	7420	51	4190
	4		15330		2090		1630
	3		13350		140		86
Total as percentage of untreated				111·0	27·8	56·0	17·0

numbered 2500 ha^{-1} at this time. These could presumably therefore become infected from stubble and act as an overwintering source in paraquat-treated fields.

The large increase in spore numbers found on volunteers sprayed with paraquat (Stedman, *Plant Pathology* (1977) **26,** 3) did not occur on unsprayed plants collected in mid-October 1977 and air dried. On these plants spore number had decreased considerably 7 days after collection, then declined slowly to 20% of the initial number after a period of 7 weeks.

Single fungicide sprays applied in either early October or late November 1977 decreased the number of spores washed from volunteer plants over the following 9 week periods by 46 and 23% (thiophanate methyl), 23 and 23% (carbendazim) 38 and 37% (benomyl) and 35 and 37% (triadimefon). Captafol (applied on the first occasion only) increased spore number by 19% over the 9-week period. (Stedman)

Spore viability. The viability of *R. secalis* spores washed from volunteer plants sprayed with paraquat in early October 1977 was compared with that of spores washed from untreated volunteers by inoculation of serial dilutions on to pot grown plants (cv. Maris Otter). Seven days after paraquat treatment, viability of spores from treated plants (29%) exceeded that of spores from untreated plants (10·6%). Two weeks later viability of spores from paraquat-treated plants had declined to less than 3% and it remained below this value for the remainder of the 6 weeks test period. Over the 9 weeks period viability of spores from untreated plants varied between 2 and 17%. From early December until late February the viability of spores from paraquat-treated stubble was measured weekly. The viability declined during December from 12·5 to 1·2%: subsequently insufficient spores were washed from the stubble samples to be detected on the haemocytometer (minimum detection limit 700 ml^{-1}). After the end of December therefore a single 5 μm drop of the washings was placed on each of 100 pot grown barley plants. These produced 33 successful inoculations in early January but only one in late February. Viability of spores from untreated volunteers varied between 1 and 39% over the 3-month period. (Stedman and Parkins)

Take-all disease. In these reports the following abbreviations are used for simplicity:

Gaeumannomyces graminis var. *tritici* = Ggt;
G. graminis var. *graminis* = Ggg;
Phialophora radicicola var. *radicicola* = Prr;
P. radicicola var. *graminicola* = Prg.

Gaeumannomyces-Phialophora ***complex: isolates from a site with little take-all.*** A noticeable occurrence of Prr on assay plants in an autumn bioassay of soil from the

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'Effect of breaks on take-all' experiment on Butt Furlong, Woburn, has been mentioned (*Rothamsted Report for 1977*, Part 1, 216). Subsequent examinations showed that although 'pale' lesions attributable to Prr were present, there were other darker lesions that resembled but were not typical of take-all. Up to about 2 years ago such lesions were few and classified as take-all; since then they have become more conspicuous and frequent and are often associated with small, discrete swollen cells. A microscopical examination of the discoloured roots of assay plants revealed several different symptoms and isolations from samples of these plated on agar included a previously undetected and, as yet, unidentified *Phialophora* sp. which was more frequent and widespread than Prr and Ggt (Table 2).

On potato-dextrose agar the *Phialophora* sp. produced a curious colony with a central olivaceous-grey bloom and much curling of marginal hyphae. It grew faster than Prg, but not as fast as Prr or Ggt. Its appearance suggested a contaminated culture but light and electron microscope studies and tests with antibiotics failed to confirm this. Germinating phialidic conidia were like those of Prg but a little wider; and swollen cells produced on host roots grown in sand were slightly larger, paler and less distinct than those of Prg. The fungus was slightly less effective than Prg in protecting seedlings from Ggt in host infection tests.

Prg is usually associated with grassland and the first few crops of consecutive cereals that may follow and therefore would not be expected to be frequent in a crop sequence experiment on a site that has grown spring barley since 1967, either continuously or with phased breaks of fallow and beans. Both Prg and Prr have controlled take-all in experiments. The *Phialophora* sp. most resembles Prg but it is not known whether it is controlling take-all in this experiment, why it has apparently increased recently and what its association with take-all-like lesions signifies. (Hornby, Henden and den Toom)

TABLE 2

Frequency of isolation of fungi in the Gaeumannomyces-Phialophora *complex from roots of young wheat plants grown in pots of Butt Furlong soil*

	Surface sterilised roots*				Washed roots†			
		% with				% with		
Root symptoms	Total no.	Ggt	Prr	*Phialophora* sp.	Total no.	Ggt	Prr	*Phialophora* sp.
1. None	25	0	4	4	25	0	0	0
2. Runner hyphae with								
a) small swollen cells	50	2	16	50	50	0	2	16
b) large swollen cells	15	0	53	0	25	0	0	8
c) other than a or b	10	10	0	50	15	0	0	0
3. Dark lesions								
a) take-all-like ±swollen cells	10	0	0	50	30	0	0	10
b) typical take-all	5	60	0	60	10	0	0	0
Pooled roots	115	4	15	34	155	0	1	8

*5 mm segments of roots immersed in 25% 'Chloros' for 20 s
†2 mm segments of roots washed in running tap water for 2 h

Take-all profiles. Our study of the distribution of take-all on the root systems of winter wheat grown under different cultivation systems continued. In 1978 a site on a London clay soil at Margaretting Essese, in which the take-all fungus was very prevalent, was studied. (The site was provided through the co-operation of ADAS and R. J. Upton

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(Farms) Ltd.) The cultivation treatments were: deep tined; shallow tined; and direct drilled. As in previous years (*Rothamsted Report for 1976*, Part 1, 263) the direct drilled plots had less take-all in the zones below 7 cm than the tined treatments in May and in the direct drilled plots a greater percentage of the infected roots were infected in the 0–7 cm zone. By July the distribution of disease down the profile was similar in all cultivation treatments, averaging 90% roots infected in the 0–7 cm zone, 62% in the 12–17 cm and 23% in the 22–27 cm zones with slightly less infection in the direct drilled plots. Of the infected roots, the percentages infected in the 0–7 cm zone at this time were identical in all treatments. As the 0–7 cm zone can be equated approximately with the root depth recovered by the standard hand sampling technique, these results suggest that July samples using this technique provide a reasonable estimate of take-all irrespective of cultivation treatment. (Prew and Stone)

Epidemiology of take-all. Earlier studies on the different amounts of take-all in second wheats after grass and lucerne leys showed the need for a method to measure the increase of inoculum in soils under first wheat crops: plant samples show few recognisable take-all lesions. For the last 4 years we have assayed soil cores (*Rothamsted Report for 1976*, Part 1, 261) taken from first and second wheat crops after oats during summer and early autumn. Last year we reported that the inoculum of the take-all fungus had recovered from the exceptionally dry summers of 1975 and 1976 and predicted that take-all would be common in second wheats in 1978. This prediction was fulfilled: in our study the second wheat after oats had 21% plants with take-all in April, increasing to 87% by July. Infectivity of soil from this crop increased consistently during May to September, ending at more than twice the amount recorded in the previous September after the first wheat. In contrast, infectivity of soil from a first wheat after oats (in another field) increased only slowly until July, then rapidly during July to September, ending at about two-thirds the amount recorded in the 1977 first wheat. It seems that second and third wheats will again be at risk from take-all attack in 1979, as, indeed, they usually are at Rothamsted.

The success of the soil assay method in measuring take-all inoculum in wheat soils during four contrasting summers suggests it will be a useful experimental technique for studying factors (such as *Phialophora*) which may affect the build-up of inoculum, especially in crops where take-all lesions are too scarce to estimate accurately. We have also begun to test the method for assessing the risk of take-all in farmers' crops on different soil types, but it is unlikely to have general application for forecasting take-all, partly because it is very laborious, partly because the severity of take-all depends on weather during crop growth at least as much as on initial inoculum. (Slope and R. J. Gutteridge)

Eyespot (*Pseudocercosporella herpotrichoides*)

Spore production and dispersal. Little is known in detail about how spores of *P. herpotrichoides* spread from infected stubble to the growing wheat crop. They are generally regarded as splash-dispersed (e.g. Glynne, *Transactions of the British Mycological Society* (1953) **36,** 46–51) although Schrodter and Fehrmann (*Phytopathologische Zeitschrift* (1971) **71,** 203–222) claim they are wind dispersed. We attempted to monitor numbers of airborne spores with several samplers placed among infected straw, spread on fallow ground to avoid the filtration effect of a growing crop; and to relate them to sporulation on the straw; to infection of wheat plants (cv. Kador) exposed on the plot for weekly periods; and to weather.

Spore numbers per straw decreased sharply after heavy rain; from 106×10^3 to

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4×10^3 after 38 mm rainfall on 5–12 May; and from 47×10^3 to 10^3 after 49 mm on 28 July–4 August, supporting the splash-dispersal view. Most spores per straw (2×10^5) were recorded in April and June and fewest, other than after rain, in August and during cold dry weather in February (2×10^3). Otherwise, weather conditions favoured sporulation throughout the growing season.

Between 21 February and 4 July the weather also favoured spore dispersal; during most weeks there was more than 4 mm rainfall and over 75% of exposed wheat plants had developed eyespot symptoms after 8 weeks in a cool glasshouse. Conditions were less favourable for dispersal between 23–30 May (0·2 mm rainfall, 45% infection), 7–14 February (0·6 mm snow, one plant infected) and 14–21 February (0·9 mm rainfall, 27% infected). After 11 July exposed plants did not develop eyespot symptoms, although it rained on most days between 22 July and 10 August and spores were still viable (50% of the spores washed from straw collected on 27 July had germinated after 5 days). Temperatures during this period may have been too high for infection to occur.

Evaluation of spore samplers. It was impossible to relate these results to concentrations of airborne *P. herpotrichoides* spores, since no sampler consistently collected large numbers of spores. A column of glass cylinders covered with gelatin-coated cellophane (0–50 cm above ground level) exposed between 1–3 March (rainfall 13 mm) collected 750 spores. Most spores (100 cm^{-2}) were collected between 5–10 cm and none above 30 cm. Between 0–5 cm numerous soil particles made it difficult to count spores collected (about 60 cm^{-2}) and it is probable some were lost in run-off water. This method would be unsuitable for routine sampling since gelatin dries quickly in dry weather and weather conditions affect the proportion of spores lost in run off water.

A Burkard suction sampler, operated at 11 litres min^{-1}, collected few *P. herpotrichoides* spores, probably because its orifice was 40 cm above ground level. Between 20 December 1977 and 3 January 1978 several hundred *P. herpotrichoides* spores were collected by a liquid impinger but few were found in subsequent weekly samples. This impinger, which operated at 20 litres min^{-1} 10 cm above ground level, collected large numbers of windborne spores and pollen grains and therefore should have collected small airborne splash droplets efficiently. Perhaps most *P. herpotrichoides* spores were carried by large ballistic splash droplets which probably bypassed its narrow orifice (diam. 15 mm). If so, it is surprising that few spores were recovered from beakers (diam 11 cm, 5 cm above ground level). The spores may have germinated as rainwater diluted the 2% phenol collecting solution, or adhered to the plastic collecting funnel.

Properties of* P. herpotrichoides *spores. During attempts to concentrate spore suspensions by centrifugation it was found that the spores adhered to some plastics (polypropylene and polycarbonate). When a centrifuge tube containing a suspension of 10^6 spores ml^{-1} was shaken, only 2×10^3 spores remained in suspension. If a few drops of 'Triton X-100' (a nonionic surfactant) were added the adsorbed spores returned into suspension. Their adhesiveness was unaffected by buffers and they did not stick to glass. (Fitt and Bainbridge)

Spread of eyespot in winter wheat. Two plots of wheat, approximately 12 m × 30 m, were sown on 1 November and 10 March with cvs. Kador and Maris Freeman respectively, separated along their length by an unsown plot of the same size. Stubble gathered in late summer from a crop severely infected with eyespot was scattered over the plots at about 0·1 kg m^{-2} on 3 November on the earlier sown and unsown plots and immediately after sowing on the later sown plot.

Pots of ten Kador seedlings, raised outdoors away from the likelihood of eyespot

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infection until GS 13 were exposed, five pots per plot, for 1 week, each week from November to June. The pots were sunk to the rim, one in the centre and the others partway towards each corner of each plot. After exposure the pots were kept on a capillary bench in a cool greenhouse for 8 weeks when the plants were assessed for eyespot infection. Except for 3 separate weeks in February and April when no rain fell, exposed plants developed 80–100% eyespot infection throughout the period. Plants exposed in the plot to be sown later usually developed about 20% infection; from the time of sowing, when stubble was also spread, infection was the same high percentage as in the other two plots. (Bainbridge and Parkins)

Twenty plants from seed sown in pots on 1 November and grown outdoors in isolation were transplanted into the earlier sown plot each week from early December until early June. The transplants were dug up in July and assessed for eyespot. Those transplanted in December had 47% of straws infected, this percentage decreasing only slightly during the winter to 40% infection on March transplants. Thereafter the percentage of straws infected fell quickly, averaging 32% of those transplanted in April, 8% of May transplants and none of the June transplants.

From the earlier sown crop a sample of 50 plants was taken fortnightly and assessed for eyespot. Eyespot developed slowly through the winter. At the end of February 3% of tillers had visible lesions, by mid-April this had risen to 22% and by July 61% of straws showed infection. During May and June leaf sheaths were becoming shrivelled, masking symptoms, while lesions on stems had not yet developed, resulting in a decrease in visible lesions (14–29%) compared with the April figure.

Results from the plants exposed for 1 week indicate that sufficient spores were dispersed during wet weather throughout late autumn, winter and spring to infect nearly all plants but, in the field, weather did not favour infection and/or lesion development until early spring. (Prew and Read)

Gibellina cerealis. The incidence of a rare disease of wheat caused by *Gibellina cerealis*, has been recorded in the alternate wheat and fallow experiment on Hoosfield since first found there in 1935 (*Transactions of the British Mycological Society* (1936), **20,** 120–122). The disease was not found in 1978. The number of infected plants found has varied from none (1936, 1978) to 411 (1961), the highest number forming too small a proportion of the crop to affect yield appreciably. Averaged over the years there have been, surprisingly, twice as many infected plants after 3 as after 1 year under fallow. The disease has very rarely been recorded on Broadbalk since 1966 and these are the only fields in Britain on which it is known to occur. (Glynne)

Diseases of grass and forage crops

Clover rot (*Sclerotinia trifoliorum*). We have begun to develop a method for testing resistance of clovers and other forage legumes to *S. trifoliorum* using ascospores as inoculum. These spores are formed in apothecia which, in the field, develop from germinating sclerotia during autumn and are thought to be the usual source of infection. To produce them artificially probably requires that sclerotia are held under conditions simulating those outdoors in late summer and autumn. We have now repeatedly produced apothecia and have confirmed and extended earlier work on the factors influencing their formation. Sclerotia are readily formed by culturing the fungus on moist bran or oat grains. The following treatments have been found to favour sclerotial germination: air-dry storage; soaking (previously dried) sclerotia in running water for several days; incubation at temperatures fluctuating diurnally, e.g. 20 h at 20°C and 4 h at 7°C. Only stipes are formed when sclerotia germinate in the dark; long-wave ultra-violet light is

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needed for apothecium development. When stipes were exposed to natural daylight or continuous 'black light', apothecial discs, asci and ascospores formed. Combinations of various light and temperature regimes are now being investigated. (Macfarlane)

Red clover necrotic mosaic virus (RCNMV). This virus was confirmed on three more farms, in Wiltshire, Devon and the Borders and, although there were generally fewer reports of RCNMV in 1978, it seems that the virus is geographically widespread in Great Britain.

In experiments to investigate the mechanism of transmission, 60% of red clover test seedlings (cv. Hungaropoly), grown outside in glazed earthenware pots containing either plants and soil or soil alone from infected sites, were shown to be infected with RCNMV after 3 to 6 and 9 months respectively. The roots of these test seedlings were found to be infected with sporangia and zoospores of an *Olpidium* sp. Drainage fluid collected from pots containing plants and soil from infected sites inoculated to *Phaseolus vulgaris* cv. The Prince produced local lesions typical of RCNMV. Similar fluid was used to water red clover test seedlings 30% of which showed symptoms after they had been overwintered and kept outdoors for 10 months.

A small box experiment was done outdoors to find whether the virus can be transmitted mechanically on machinery. After three cuts with electric shears at 5-week intervals, plants showing virus symptoms increased from 8 to 25%. (Bowen and Plumb)

Cucumber mosaic virus from white clover. Attempts to transmit this virus back to white clover using highly concentrated preparations from tobacco cv. Xanthi-nc failed. Aphid transfers using *Myzus persicae* succeeded only when the source plant was white clover and the test seedlings were very young. The aphid *Acyrthosiphon pisum* failed to infect white clover even under these conditions. The virus and a cucumber mosaic virus isolate from swede were both transmitted readily to crimson clover by inoculation with infective tobacco sap. (Govier)

Resistance to ryegrass mosaic virus (RMV) in perennial ryegrass. It has previously been reported (*Rothamsted Report for 1974*, Part 1, 231), that the perennial ryegrass cultivar Endura is especially difficult to infect with RMV. Research elsewhere has suggested that apparently healthy plants may be carriers of mild forms of RMV. However, it has now been confirmed that most glasshouse-grown plants of Endura have identifiable symptoms when infected with RMV and that it does require either more inoculations or more concentrated inocula to achieve the same proportion of diseased plants of Endura than of the more susceptible cultivar Gremie. (Gibson and Pickering)

In two plants of Endura which, because symptoms were very mild, were checked electronmicroscopically, RMV particles were only rarely found. In comparison with S.24 infected at the same time, the concentration of RMV particles in the sap of these two plants was about nine and about 36 times less. Inocula prepared from the Endura plants were considerably less infectious when manually inoculated to S.22 Italian ryegrass than inocula of the same concentrations of plant material prepared from the S.24. The RMV passaged through these Endura once again attained normal concentrations when inoculated to S.22 plants. It appears, therefore, that these two Endura plants possess an ability to restrict virus multiplication or to degrade virus. The significance of this form of resistance and its value compared with that of direct resistance to infection remains to be investigated. (Gibson, Pickering and Woods)

Diseases of grain legumes

Root rot of lupins, *Lupinus albus* cv. Kievsky. A major problem with spring-sown lupins has been their late ripening. Autumn-sown lupins ripen earlier but suffer unacceptably

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large losses during winter from root-rot involving species of *Pythium*, *Fusarium* and *Botrytis*. An attempt to control these losses with fungicides applied to the seedbed and to the seed was not very successful but indicated that protection against a wide range of soil fungi was necessary. Thus October sown seeds emerged well but most seedlings perished during winter in untreated plots and where benomyl (25 kg a.i. ha^{-1}) thiram (40 kg a.i. ha^{-1}) or drazoxolon (23 litres. a.i. ha^{-1}) were used singly. However, 35% survived where both benomyl and thiram were applied to the seedbed and 14% where 0·1% a.i. of each was mixed with the seed. The same mixture of chemicals applied as a seed dressing also gave the best emergence of March sown seed, 75% compared with 69% from untreated seed. 'LS 74783' at 120 kg a.i. ha^{-1} and 'CGA 48988' (Ciba–Geigy) at 4 kg a.i. ha^{-1} failed to increase emergence or survival of March sown seed when applied to the furrow at sowing, or of October sown seed when applied to the soil in February when root-rot was already well established.

Pot experiments showed that several *Pythium* species including *P. ultimum* are major pathogens of lupin seeds and young seedlings. *Botrytis cinerea* and *Fusarium avenaceum* caused severe damage before emergence but only minor damage to emerged seedlings. Emergence was decreased slightly by *F. oxysporum* var. *redolens* (but not by other isolates of *F. oxysporum*), *F. solani*, *Rhizoctonia solani*, *Gliocladium roseum* and a *Mucor* sp. Different fungicides controlled different fungi when applied as drenches after planting lupin seeds on agar discs of fungus mycelium in pots of potting compost. 'CGA 48988' increased emergence in the presence of *Pythium* from nil to 89% but had little effect against *F. avenaceum* or *B. cinerea*, whereas benomyl gave full protection against *F. avenaceum* and *B. cinerea* but none against *Pythium*. Drazoxolon and thiram were very effective against *B. cinera* but only partially effective against *Pythium* and *F. avenaceum*.

Root rot is always much more severe on seedlings overwintering in the field than those grown in field soil in the glasshouse, even with additional inoculum. It seems that frost damage and the fact that seedlings grow very slowly during winter are important factors affecting their susceptibility to root-rot. (Salt and Smalley)

Virus diseases of lupins. Three virus isolates from white lupin and one from white clover were compared in biological and physical properties with known cultures of bean yellow mosaic virus (BYMV) and clover yellow vein virus (CYVV). One of the lupin isolates (L2) and the clover isolate (184.4) were identified as strains of CYVV and the other two lupin isolates (L3 and RG2) as strains of BYMV. All CYVV and BYMV isolates caused lesions on inoculated leaves of *Chenopodium amaranticolor* and *C. quinoa* but, whereas most BYMV isolates infected only *C. amaranticolor* systemically, most CYVV isolates infected only *C. quinoa* systemically. Exceptions were L2 which caused occasional systemic chlorotic flecks in *C. amaranticolor*, BYMV-B which failed to infect *C. amaranticolor* systemically, and RG2 which caused a severe systemic disease in both species. L2, but not 184.4, and all BYMV isolates infected field bean (cv. Herz Freya) and broad bean (cv. The Midget) systemically.

BYMV isolates were best purified by extracting in 0·1M-tris buffer pH 9 and clarifying the sap by emulsifying with a mixture of chloroform and carbon tetrachloride and centrifuging. CYVV isolates were clearly distinguished by their instability in the pH 9 buffer and they were purified by extracting in 0·1M-tris buffer pH 8 followed by treatment with 2·5% (v/v) 'Triton X-100'. Sedimentation coefficients of the various isolates ranged from 140–145*S* but the results were not consistent enough to determine whether true differences existed among the isolates. In isopycnic centrifugation in CsCl solutions at 25°, a mixture of isolates formed one band at a density of 1·322 g ml^{-1} containing the CYVV isolates and a second band at 1·327 g ml^{-1} containing all the BYMV isolates.

In microprecipitin tests, antisera to each of the BYMV isolates reacted almost to titre

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(1/800–1/1600) with the remaining BYMV isolates but titres against the CYVV isolates were three or four two-fold dilution steps lower. The L2 antiserum showed similar differences when tested against the homologous virus and each of the BYMV isolates but the 184.4 antiserum failed to distinguish clearly between the CYVV and BYMV isolates. Suitably diluted antisera were used successfully in slide agglutination tests to distinguish between CYVV and BYMV isolates. (Govier and Nogay)

Root diseases of field beans (*Vicia faba*). Field beans cv. Minden sown at the end of March had healthy roots until early August when superficial blackening first appeared and increased until plants became senescent. *Fusarium* spp. and *Cylindrocarpon* spp. were commonly and *Pythium* spp. rarely isolated from pieces of blackened roots. Benomyl, thiabendazole, 'LS 74783' and 'CGA 48988' were applied as seed-dressings and as foliar sprays in July and benomyl and 'CGA 48988' were also applied to the soil before sowing. None of the treatments affected the disease rating of roots. Thiabendazole applied with a 3% methyl cellulose sticker at the unusually high rate of 11 g kg^{-1} of seed delayed emergence, stunted growth and yielded significantly less grain (4·59 t ha^{-1}) than controls with sticker only (5·79 t ha^{-1}). Other treatments had little effects on yield but benomyl applied to seed at 9 g kg^{-1} yielded most grain (6·00 t ha^{-1}) and more than benomyl applied at 20 kg ha^{-1} to the soil at planting (5·39 t ha^{-1}). (Salt and Smalley)

Other observations on fungus and virus diseases of field beans are given in Field Experiments Section Report, p. 120.

Chocolate spot on winter beans. Adjacent latin-square experiments had plots sprayed with benomyl at 0·6 kg a.i. ha^{-1} once (26 May) twice (26 May and 16 June) four times (28 April, 26 May, 16 June and 18 July) or left unsprayed, to assess the effect of chocolate spot on yield. The variety Throws MS was sown at 250 kg ha^{-1} and 18 cm row spacing on 14 October 1977 in 0·004 ha plots. One experiment was irrigated with 15 mm of water using overhead sprinklers each week from early June if natural rainfall during the week was less than 15 mm. Irrigation increased crop height from 140 cm to 161 cm. Although the number of pods per stem was also increased from 5·29 to 5.89 most nodes of the extra growth did not bear flowers. The mean yield of the irrigated experiment was 16% less than that of the unirrigated even though amounts of chocolate spot were the same in the two experiments.

Each application of benomyl approximately halved the amount of chocolate spot which developed on leaves before they senesced. Thus on 9 June the lowest green leaves in unsprayed plots had 37·5% disease, once sprayed had 16·9% and twice sprayed 8·3%. On 20 July upper leaves were 16·7% diseased in unsprayed plots, 9·6% in once sprayed, 4·4% in twice sprayed and 3·7% in those sprayed four times. On plots sprayed four times the early spray had no effect on disease on upper leaves by this date and the last spray had only just been applied.

Yield was related to the amount of disease. In the unirrigated experiment unsprayed plots yielded 5·82 t ha^{-1}, one spray increased yield by 0·31 t, two sprays by 0·79 and four sprays by 0·92. The unsprayed plots in the irrigated experiment yielded 4·65 t ha^{-1} and the equivalent increases in sprayed plots were 0·48, 0·90 and 1·17 t. Thus most yield increase resulted from protecting the crop from the beginning of flowering to mid-July, i.e. protecting leaves at the fertile nodes.

Neither *Botrytis cinerea* nor *B. fabae* isolates taken from these experiments showed any tolerance of benomyl in culture. (Bainbridge and Finney with Cayley)

Vicia cryptic virus. Further work on the spherical virus-like particles, provisionally named vicia cryptic virus (VCV), in field beans and broad beans (*Rothamsted Report for*

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1977, Part 1, 222) has confirmed their presence in a high proportion of plants of cultivars Maris Bead, Throws MS and Triple White. However, attempts to transmit VCV by mechanical inoculation, grafting and dodder have so far failed. VCV is seed borne and tests with two cultivars suggest that it is transmitted through about 75% of seeds set by self-pollinated plants. Seed derived by self-pollination of healthy plants invariably gives healthy progeny.

Attempts to purify and concentrate VCV have been hampered by the low virus concentration and loss of virus through aggregation and adsorption to normal plant material. Partially purified preparations of VCV have been made from Throws MS, Minden and Maris Bead. When centrifuged to equilibrium in CsCl solutions each preparation gave a major and minor band corresponding to buoyant densities of 1·38 and 1·39 g ml^{-1} respectively.

Similar amounts of VCV were present in the leaves and roots of both Throws MS and Maris Bead plants but stems had much less virus. Leaves of 6-week-old plants of these two cultivars yielded two to three times as much VCV as 2-week-old plants.

No virus-like particles were detected by concentrating extracts from seemingly healthy glasshouse grown plants of pea (5 cvs), French bean (7 cvs) and white lupin (1 cv), nor from *Vicia narbonensis* and *V. sativa*. However, particles of similar size and shape to VCV were found in apparently normal alsike clover and lucerne plants. Smaller particles (*c.* 25 nm in diameter) were isolated from crimson clover. These were transmitted to *Chenopodium quinoa* by mechanical inoculation. (Kenten, Cockbain and Woods)

Diseases of Brassica crops

Oilseed rape. Last year we reported that benomyl seed treatment (5 g kg^{-1}) followed by two foliar sprays of benomyl (1·12 kg ha^{-1}) gave good control of light leafspot (*Pyrenopeziza brassicae*) but did not increase yield of oilseed rape (*Rothamsted Report for 1977*, Part 1, 222; *Transactions of the British Mycological Society* (1978) **71**, 425–451). A similar experiment was repeated on the same site on Summerdells in 1978, using a basal application of dalapon and propyzamide (1·12 + 1·12 kg ha^{-1}) as herbicide and split applications of benomyl, in an attempt to separate the effect of seed treatment from foliar sprays. This year benomyl applied as a foliar spray in early February and again in late April resulted in a yield increase, presumably because disease was more prevalent. Benomyl seed treatment alone did not affect light leaf spot or yield significantly. Two or more applications of benomyl, as a seed treatment plus one or two sprays, significantly decreased incidence and severity of light leafspot and canker (*Leptosphaeria maculans*) and increased yield by 28% in a susceptible cultivar. However two sprays without seed treatment resulted in the greatest yield increase (33%) in this cultivar. Benomyl appeared to have increased the incidence of downy mildew (*Peronospora parasitica*) when disease was assessed in early June although differences between treatments were not statistically significant.

No single measurement of any disease (% plants or % leaves infected, disease index) was significantly correlated with yield when the correlations were estimated from residual variation, although all values for disease severity (disease index) indicated a negative correlation. However, when comparisons between treatments, in addition to error contrasts, are included in multiple regression analysis it is clear that increases in yield following benomyl were closely related to control of light leaf spot. Differences in severity of light leaf spot explained a substantial part of variation in yield (partial regression coefficient $-0{\cdot}24 \pm 0{\cdot}057$). When data for canker are included in the analysis a further, but not quite significant ($-0{\cdot}17 \pm 0{\cdot}106$), proportion of variation is explained. The

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inclusion of data for downy mildew did not account for further variation ($-0{\cdot}11 \pm 0{\cdot}122$).

Benomyl spray applied in early October and again in mid-January had a considerable cosmetic effect on a site (Great Field) where self-sown rape (cv. Victor) had grown for 5 consecutive years and where all three diseases were endemic. Although incidence of light leafspot on plants was little affected, incidence on leaves was decreased from 74 to 55%, and severity halved. Yield was increased (from 0·43 to $0{\cdot}58 \pm 0{\cdot}081$ t ha^{-1}) but not significantly, the low yield generally reflecting the build up of disease on this site. In a further experiment with cv. Primor, where disease was not as prevalent or severe as on the previous sites and where a single foliar application of benomyl was delayed until late April, disease in June and yield were little affected.

Although outclassed cultivars (Eurora and Victor) were used in some of these experiments, and most benefit to yield was derived from application of fungicide to the disease-susceptible cultivar Eurora, these results imply that early (certainly before end April) use of effective fungicides could be economic in terms of yield response in years when disease is severe. (Rawlinson and Muthyalu)

Potato diseases

As in 1977, planting conditions were far from ideal and good seed beds were difficult to obtain. Some crops were planted in April when the land was fit but it was mid-May before many experiments were planted. Crops emerged slowly in cold wet soils and stem canker (*Rhizoctonia*) was prevalent at Rothamsted and Woburn. Blackleg in Pentland Crown, evident in June, was not unexpected in view of its high incidence in the seed crop in 1977. June was wet and on 3 July late blight was found locally on dumped King Edward. Weather favoured blight but timely spraying proved effective in farm crops. However, in unsprayed areas such as in one of the groundkeeper experiments, not only were plants destroyed but so were the rooted stem cuttings planted out to detect other diseases. Drier weather from late August caused lesions to dry out and by mid-September active lesions were difficult to find. Tuber blight was rare, except in one small experiment with much irrigation which also showed a high incidence of pink rot. October was dry and warm and lifting conditions ideal and all potatoes were lifted before the end of the month. During growth, stolon pruning by *Rhizoctonia* was common as was black scurf on tubers after harvest. Pycnidia of *Phoma exigua* were prevalent on desiccated stems. Yields of about 50 t ha^{-1} were recorded.

Diseases caused by bacteria

Spread of* Erwinia carotovora *varieties. The ability to distinguish serologically between the two *Erwinia carotovora* vars. *atroseptica* (blackleg) and *carotovora* (tuber soft rot), when present together in induced tuber rots, has enabled spread from inoculated seed tubers placed in the crop (*Rothamsted Report for 1976*, Part 1, 271) inoculated with one variety, and stems (*Rothamsted Report for 1977*, Part 1, 224) with the other to be traced on the same plant. In a field experiment in 1978 tubers and stems were inoculated on or about 3 July (1), 25 July (2) and 29 August (3) and samples taken 2, 4 and 8 weeks later and at a final harvest on 17 October. Tubers inoculated at any date with var. *carotovora* rotted rapidly and, except for 27 September (3), var. *carotovora* was not detected in soil or in induced progeny tuber rots. When inoculated to stems it remained readily isolable but could not be recovered from soil nor, except for 14 August (2), from induced progeny tuber rots.

Tubers inoculated with var. *atroseptica* also rapidly degenerated after placement but except for 14 August (2), 13 and 27 September (3) it was not isolated from soils. It was

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recovered from induced progeny tuber rots on 24 July and 7 August (1) but not from later samples. Stem lesions remained active throughout the season and var. *atroseptica* was isolated from soil on 24 July and 22 August (1), 14 August (2) and 27 September (3), and from induced progeny tuber rots on 24 July, 7 August and 17 October (1), 14 August (2) and 13 September (3).

The pattern of spread indicates that most occurred during the wet cool weather of July and early August with little or none during the increasingly dry September and October. The weather (unlike previous seasons) seemed to favour the spread of var. *atroseptica* and not var. *carotovora*. Inoculum from stem lesions was more effective in contaminating progeny tubers than that from inoculated seed tubers placed among them. The increasing difficulty in inducing tubers to rot and in recovering inoculated strains suggests that populations of these bacteria declined as soils dried. (*Rothamsted Report for 1975*, Part 1, 267). (Lapwood and Harris)

Potential bactericides. Chemicals have been tested for their ability to decrease bacterial soft-rotting of wounded potato tubers by the use of an *in vivo* technique (*Rothamsted Report for 1977*, Part 1, 224). Chemicals consistently producing significant decreases in soft-rotting are 5-nitro-8-hydroxyquinoline, chlorine dioxide, 8-hydroxyquinoline and 'SD 740823AX'. Reductions of 89, 62, 56 and 42% (compared with water-dipped controls) respectively have been recorded. The results support the view that the potential control by chemicals of bacterial soft-rotting in practice is worthy of further investigation.

In vitro tests have also been done using a range of bacteria associated with potato soft-rotting grown on agar plates. No chemical effectively suppressed the growth of all the species of bacteria but 5-nitro-8-hydroxyquinoline was the most effective against var. *atroseptica* and var. *carotovora* with a concentration causing 50% inhibition of growth (IC50) of 0·2 ppm. Reliance upon the results of *in vitro* studies for the selection of candidate chemicals has proved to be misleading occasionally. 'Elbadyne' (10% dichlorophen + synergist, Winton Laboratories) had an IC50 of 2·5 ppm for var. *atroseptica* and 5.5 ppm for var. *carotovora* whilst chlorine dioxide was not effective against either at 10 ppm. However, in our *in vivo* test, chlorine dioxide reduced soft-rotting by 62% but 'Elbadyne' had no significant effect. (Harris)

Seed treatment. The importance of the degenerating mother tuber as a source of contaminating bacteria for progeny tubers has been reported (*Rothamsted Report for 1976*, Part 1, 271; *Rothamsted Report for 1977*, Part 1, 224). Progeny tubers taken from blackleg-infected plants in 1977 were treated with chemicals by dipping immediately after digging and planted in 1978 to see if any treatment could prevent or reduce rotting of the mother tuber and eliminate this source of contaminating bacteria. None of the chemicals had any significant effect on rotting of the mother tuber, plant vigour, yield or amount of rot observed in progeny tubers, when induced to rot using the 'bucket test' (*Rothamsted Report for 1977*, Part 1, 224–225). (Harris and Lapwood)

Gangrene (*Phoma exigua* var. *foveata*)

Survival in soil. Investigations on the survival of the pathogen after inoculation of soil (*Rothamsted Report for 1977*, Part 1, 225) were extended to a wider range of moisture contents, four soil types and six different fungal isolates. Experiments ran for 9 to 12 months at 10°C and populations were then assessed using the Arran Banner slice technique and by dilution on to selective agar media. No differences in size of population were detected between different isolates or between four soil types (sandy-loam, loam,

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clay and peat) if compared at the same moisture content (measured as % water holding capacity). Populations were larger the drier the soil except that in very dry conditions (below 20% water holding capacity) they were as small as in soils kept at or near field capacity. Considering results from several experiments in the last 4 years, it seems unlikely that the soil would provide a significant reservoir of the pathogen between potato crops in a rotation.

Infection of stems. Pycnidia of *P. exigua* developed extensively on dying potato stems in field experiments in 1977 and 1978. On plants grown from seed tubers with gangrene or from tubers contaminated shortly before planting with a soil slurry containing var. *foveata* pycnidiospores, the pycnidia which developed were mostly of the var. *foveata*, whereas on plants grown from sound seed not artificially contaminated the common saprophyte var. *exigua* predominated. In 1978, plants of two cultivars were grown in a field experiment from seed contaminated with slurries containing different concentrations of pycnidiospores. On two occasions, green stems were sampled, pieces surface-disinfected, and sections plated aseptically on to malt agar. The pathogen was occasionally detected within the stems although the seed tubers were not rotting and there were no external stem symptoms. Frequency of isolation and of the development of pycnidia of var. *foveata* after haulm desiccation were greater the larger the spore concentration in the seed tuber slurry.

In a glasshouse experiment, plants were grown from sound seed tubers (control), from rotting (inoculated) seed tubers and from sound seed tubers but with the stem bases inoculated shortly after emergence by the external application of a spore suspension. On five occasions during growth, stems were sampled and isolations made from different parts of the shoot. The pathogen was never isolated from stems of control plants but, out of 80 stems tested per treatment, it was isolated from five following seed inoculation and 22 following stem base inoculation. Pycnidia developed on these plants only after haulm desiccation.

These results suggest that the pathogen can invade living potato stems from contaminated soil, but without producing symptoms and without evidence of the fungus until the haulm dies. (Adams)

Sources of inoculum. The relative contributions of contaminated or infected seed tubers and stem infection to the contamination of progeny tubers were investigated in a field experiment in 1977. Tubers were sampled on four occasions at fortnightly intervals after haulm desiccation from plots with all combinations of three seed treatments (none, contaminated with infested slurry or rotting with gangrene) and three stem treatments (none, cut off at ground level or inoculated with the pathogen shortly before haulm desiccation). Tubers were wounded uniformly and gangrene incidence scored after 12 weeks' incubation at 5°C. Disease was slight on progeny from plots where neither the seed nor the stem was infected. On all other treatment combinations, incidence was similar at each harvest date but increased with subsequent harvests from *c.* 25 to *c.* 65% of wounds infected. Thus cutting the haulm did not decrease progeny tuber contamination (despite the profuse development of pycnidia on uncut stems where seed tubers were contaminated or rotting) and stem inoculation increased progeny contamination only where seed tubers were uninfected.

These results underline the importance of seed infection (either as surface contamination or as active rots) as the principal source of inoculum for progeny tubers. Under the conditions of 1977, stem infection which was related to seed tuber inoculum, surprisingly made no significant contribution to inoculum levels in the soil. (Adams)

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The use of fungicides against tuber-borne pathogens

Effects of seed treatments on diseases in stored crops. Last year's report described experiments in which tuber samples from four seed stocks were treated with thiabendazole (133 mg kg^{-1}) in March before sprouting and planted on two farms in Lincolnshire. Results showed that yields, although 8% larger from a healthier (stem cutting) stock, were not affected by treatment. Infection of progeny tubers at lifting was considerably decreased by seed treatment and disease assessments after storage at Sutton Bridge Experimental Station confirm that late seed treatment can have beneficial effects in store. Mean incidence of skin spot was decreased from 13 to 0·1% and from 36 to 3% and black scurf from 37 to 6% and from 26 to 4% on farms 1 and 2 respectively.

Although infection of tubers by *Helminthosporium* at lifting was significantly decreased by seed treatment the incidence of silver scurf on stored tubers was less affected. This suggests that the disease spread over the tuber surface from small infections or that infection spread from tuber to tuber within the store which also contained tubers from untreated seed. Black dot was slightly decreased by seed treatments but gangrene was usually as prevalent on the produce from treated as from untreated seed.

In 1977–78 experiments were also made on six farms in Lincolnshire. In March 1 t of farm seed was treated with thiabendazole (12·3 mg kg^{-1}) before planting in a plot situated in a field planted with untreated seed of the same stock. Eight 1 t samples from the produce of untreated and treated seed from each farm were stored at Sutton Bridge. At the end of storage, treatment decreased the mean incidence of skin spot from 33 to 10%, of black scurf from 24 to 19% and of silver scurf from 46 to 36%. Gangrene and black dot were not affected.

Control of stem canker* (Rhizoctonia) *by seed treatment. The recent increased prevalence of stem canker and black scurf led us to re-examine control by fungicide seed treatment. Previous experiments showed that benomyl and thiabendazole were effective and more recently we have found that some fungicides applied to sprouts before planting prevent stem canker originating from soil-borne inoculum.

On a farm at Thame, Oxon. spraying Pentland Crown seed (60% tubers with black scurf) with thiabendazole (26 mg kg^{-1}) or iprodione (15 mg kg^{-1}) before sprouting decreased stem canker; more importantly, the amount of stolon pruning was greatly decreased as was the incidence of black scurf on the produce. Iprodione increased yield by 40% and thiabendazole by 30%.

At Rothamsted and Woburn stem canker and stolon pruning on plants from Pentland Crown seed with black scurf were decreased by dusting seed with benodanil or maneb but most by iprodione or thiabendazole. Application of iprodione, benodanil or thiabendazole dusts to sprouts at planting decreased stem canker but had less effect on stolon infection. Maneb treatment of sprouts did not decrease stem or stolon infection. Iprodione, benodanil or thiabendazole dusts sprinkled over soil and seed tubers in furrows (11 kg ha^{-1}) before ridging also decreased infection. On both farms iprodione increased the number of stems per plant and also the number of stolons and tubers per plant irrespective of method of application. All dusts contained 5% active ingredient. (Hide and Cayley)

Tests for fungicides active against tuber-borne pathogens. Fungicides active against individual or groups of pathogens have been found in recent years and two (2-aminobutane, thiabendazole) are in commercial use. Because these have a narrow spectrum of activity (2-aminobutane), have physical properties that hinder their efficient use (thiabendazole) or involve difficulties of application, it seems desirable to seek alternatives. Candidate chemicals are tested *in vitro* and *in vivo* against *Phoma exigua* var. *foveata*,

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Polyscytalum pustulans, *Rhizoctonia solani*, *Helminthosporium solani*, *Fusarium solani* var *caeruleum* and *F. sulphureum*.

In vitro *tests*. Of 26 materials tested in agar culture thiabendazole, benomyl, carbendazim, 'NF48', imazalil, tridemorph and guazatine were active at low concentration (< 1 ppm) against all the test fungi except *H. solani*: nuarimol and fenarimol were less active against *R. solani* and *Fusarium* spp. Benodanil and 'Terrazole' were active only against *R. solani*. Mycelial growth of *H. solani* was unaffected by most materials, including thiabendazole and carbendazim, up to 100 ppm. The effectiveness of these two compounds in preventing silver scurf (*Rothamsted Report for 1977*, Part 1, 227) may be related to inhibition of sporulation. Growth of *H. solani* was decreased by low concentrations (< 6 ppm) only of fenarimol, nuarimol, tridemorph and imazalil.

Germination of *P. exigua* var. *foveata* pycnidiospores was not affected by solutions of tridemorph, iprodione or triadimefon up to 1·5 ppm whereas thiabendazole, nuarimol and imazalil decreased germination by about 50% at 0·5 ppm. Few spores germinated in solutions of guazatine at 0·125 ppm. (Hide, Mayne, Tanveer and Cayley)

In vivo *tests*. The systemic activity of fungicides was tested by applying a soil drench (50 ppm) three times a week for 6 weeks to plants in pots and inoculating stems after 4 weeks with *P. exigua* var. *foveata*. Lesion development was prevented by thiabendazole, imazalil, nuarimol and 'RH 2161' but not by guazatine, tridemorph, 'Terrazole', hymexazol or benodanil. Lesions were smaller on plants grown in sand than in peat/sand compost. Sample leaves were removed and incubated on water agar inoculated with *R. solani*. Most treatments decreased the invasion of leaves by *R. solani* which was least on plants grown in sand treated with thiabendazole, benodanil, tridemorph, guazatine, tricyclazole and 'RH 2161'. These results indicate systemic transport of fungicides or derivatives from roots to leaves and also activity against *P. exigua* var. *foveata* and *R. solani*. Soil applications of tridemorph, nuarimol and tricyclazole also prevented infection of leaves by powdery mildew (*Oidium* sp.).

Sprouts on seed tubers were treated with fungicides before planting in soil infested with *P. pustulans* or *R. solani*. Stem base infection by *P. pustulans* was decreased by thiabendazole and iprodione and stem canker (*R. solani*) by iprodione, benodanil and triadimefon, suggesting that these fungicides become systemic in sprouts and protect growing shoots from infection by soil-borne inoculum.

Control of gangrene and dry rot during storage was tested by immersing tubers in soil-slurry containing *P. exigua* var. *foveata*, *F. solani* var. *caeruleum* or *F. sulphureum*, drying overnight, wounding uniformly followed by dipping in fungicide solutions at 1·0, 0·1, 0·01 or 0·001% a.i. After 12 weeks at 5°C, 90% control of gangrene was achieved by thiabendazole, carbendazim and triadimefon at 0·1% and by imazalil, nuarimol and 'RH 2161' at 0·01%. Dry rot caused by *F. solani* var. *caeruleum* was decreased only by thiabendazole and carbendazim at 0·1% after eight weeks at 10°C whereas imazalil, nuarimol and 'RH 2161' were also effective when the disease was caused by *F. sulphureum*.

To test for effects of seed treatments on infection of plants and progeny tubers seed was dipped in fungicide solutions before sprouting. Infection of stem bases and tubers by *P. pustulans* and *R. solani* was decreased by thiabendazole, imazalil, nuarimol and 'RH 2161' and by *R. solani* only, by tridemorph. Few eye plugs from control progeny tubers produced conidiophores of *H. solani* but none were found after seed treatment with amizalil, nuarimol or 'RH 2161'. (Hide and Cayley)

Glandular hairs and insect resistance of wild potatoes. In addition to four-lobed glandular hairs on their foliage, certain seedlines of *Solanum berthaultii* and *S. tarijense* have longer

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hairs with glandular tips secreting a sticky fluid; homologous hairs on other seedlines terminate in pointed tips. Crossing experiments among these wild species indicated that the presence of this sticky tip is controlled by a single dominant gene. In an experiment with five hybrid families, progeny with sticky-tipped hairs had, on average, 60% fewer *Myzus persicae* than had progeny with pointed-tipped hairs, 2 weeks after infestation. When *S. berthaultii* was hybridised with the cultivated diploid *S. phureja* or the tetraploid *S. tuberosum*, first generations had only rudimentary glandular tips, indicating that in these crosses at least one recessive gene was also involved. In second generations a moderately large proportion (*c.* 20% and 10% respectively) had sticky-tipped hairs, indicating the possible involvement of only one recessive in addition to the dominant gene. (Gibson)

Potato virus diseases at Rothamsted. When counts were made at the beginning of July, plots planted with King Edward seed grown at Rothamsted in 1977 contained 3% potato virus Y (PVY) and 0·3% potato leaf roll virus (LR). Pentland Crown had no PVY but 0·4% LR. Fewer *Myzus persicae* were trapped at Rothamsted than in any year since the Rothamsted Insect Survey began and no current season virus spread was detected in inspections of the 1978 seed crop made in September. (Govier)

Staff and Visiting Workers

A highlight of the year was the celebration by present and past members of staff of the Department to mark our 60th anniversary. We were especially pleased to have a founder member, Dr. Mary Glynne, as guest of honour and to number Lady Marjorie Bawden, the Director and several retired members among our guests.

During the year F. Bell, Mrs. R. Bowen, Mrs. M. J. Evans, P. T. Gans, R. A. Hill and B. T. Webster left and Mrs. M. J. Driver, Mrs. R. Gutteridge (supported by the Home-Grown Cereals Authority), Miss M. Heger and S. D. Prior were appointed. Cadbury Typhoo Limited continued their support of Miss H. Davies, the Perry Foundation that of J. Payne and the Potato Marketing Board that of R. I. Harris. N. White continued his studies as an ARC postgraduate student and a second ARC studentship was taken up by K. Delaney. P. H. Gregory continued to work at the invitation of the Lawes Agricultural Trust. S. J. Eden-Green's contract with the Ministry of Overseas Development on Coconut Lethal Yellowing disease in Jamaica was extended to allow a period of home study at the John Innes Institute, Norwich.

Dr. S. Grasso, Mr. G. G. F. Kasdorf, Mr. A. Nogay, Mr. M. Tanveer and I. Wayo spent periods of from 5 weeks to 12 months in the Department, mostly undergoing training in virology. M. R. Almond, a CASE student spent 9 months in the Department, jointly supervised at Imperial College and Rothamsted. J. J. McFadden joined the Department under a similar arrangement. Miss A. Burton, Miss S. P. Pickering, Miss J. Smalley, A. Stone and S. Unsworth were sandwich course students and Miss A. den Toom spent 3 months as a voluntary worker.

The Department was well represented at the International Plant Pathology Congress in Munich in August and members were active in the proceedings and in the associated meetings pre- and post-Congress. D. Hornby was a member of the programme sub-committee for the section on soil-borne pathogens.

R. W. Gibson returned from a second period at the International Potato Centre (CIP), Peru, working on potato glandular hairs, visiting Cornell University on the return journey, where his findings are being exploited in a substantial breeding programme.

R. H. Kenten visited Jamaica to review the work of the Lethal Yellowing Research

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team and spent 2 weeks at the Central Plantation Crops Research Institute's stations based on Kerala, India, to explore possible collaboration in research on coconut root-rot (wilt) disease.

J. Lacey visited Iran for 2 weeks at the invitation of the International Agency for Research on Cancer (WHO) to examine and sample grain in store in areas where oesophageal cancer is common.

D. H. Lapwood attended and gave a paper at the 15th Planning Conference of the CIP, Peru and also attended the IVth International Conference on Plant Pathogenic Bacteria in Angers, France.

R. T. Plumb spent 6 months as visiting scientist at the Plant Research Institute, Victoria, Australia, by invitation of the Victoria Department of Agriculture working on barley yellow dwarf epidemiology and gave invited papers or seminars in Adelaide, Brisbane and Melbourne during his stay.

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