ROTHAMSTED RESEARCH

Report for 1975 - Part 1

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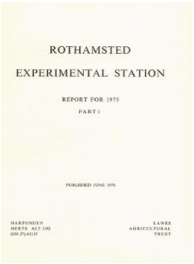

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Introduction

Once again weather has had a greater effect on yields than most of our major pathogens, especially on spring sown crops. Potato yields were among the poorest on record; planting was delayed by wet soggy soils, emergence was often poor, and in the drought from mid-May to mid-September unirrigated crops suffered badly. Potato ground-keepers were unusually numerous, probably as a result of recent mild winters, and aphid numbers exceeded any counts over the last seven years. Potato virus Y spread rapidly and by the end of August almost every plant in many experiments showed leaf-drop streak symptoms. For the first time since 1967 a crop of King Edward grown to provide seed for 1976 had to be discarded. The introduction of stem-cutting propagation into potato seed production promised at first to be a major advance for producing healthier seed, but we have been disappointed at the rate at which stocks have become re-infected unless protected by fungicide treatments (p. 270). Advantages in using healthier seed may be much greater than the 6–10% increase in yield recorded at lifting, because the

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harvested tubers developed much less skin spot, gangrene and silver scurf during storage than those from commercial stocks (p. 270): in 1975, healthier seed yielded 22% more ware than commercial stocks where crops were irrigated (p. 271).

Spring sown field beans (*Vicia faba* L.) suffered from drought and yields were below 2·00 t ha^{-1} even on plots where weevil-borne viruses were controlled by insecticides (p. 262). By contrast winter sown beans grew well, escaped serious loss from chocolate spot and yielded as much as 4·37 t ha^{-1} (p. 263).

With the large populations of aphids it is not surprising that barley yellow dwarf virus was widespread; crops sown late in April had many more infected plants than those sown in March or late autumn (p. 251). Mildew was the principal cereal leaf pathogen and as expected its severity increased with lateness of sowing (p. 251). Controlling mildew with tridemorph sprays increased responses of spring barley to increasing amounts of nitrogen fertiliser (p. 251).

We have more evidence showing that the rate of take-all increase is slower on wheat grown in soil containing much *Phialophora radicicola* var. *graminicola* (PRG). However, a high infestation of PRG was found not only after grass but also after lucerne on Fosters, a field with a long history of arable crops, and persisted through a potato–wheat–wheat sequence (p. 255). Taxonomic studies of the *Gaeumannomyces/Phialophora* complex have revealed a perfect stage for PRG which appears to be a new species of *Gaeumannomyces* (p. 256), but virus particles found in an isolate of PRG appeared to be different serologically from those found in *Phialophora radicicola* var. *radicicola*, *Gaeumannomyces graminis* var. *avenae*, *Gaeumannomyces graminis* var. *graminis* and *Gaeumannomyces graminis* var. *tritici* (p. 256).

Work on grass viruses continued with special attention to ryegrass mosaic virus and the behaviour of its vector (p. 258), but even our small effort on fungal diseases of grasses ceased when E. W. Broom departed in February and was not replaced.

There was an increased effort on the pathology of new crops. Grain lupins grown for the first time at Rothamsted were infected by two aphid-borne viruses, bean yellow mosaic and one resembling clover yellow vein (p. 263). Both were damaging to the small proportion of plants infected. *Fusarium* wilt was also found and powdery mildew became severe late in the season. Oil seed rape suffered more from leaf diseases than in 1974, especially where dalapon herbicide had been used. *Gloeosporium* (*Pyrenopeziza*) leaf spot and downy mildew were both very prevalent (p. 264). By contrast maize crops were notably free from damaging levels of both fungal and virus diseases (p. 260), even where grown on the same land for several years.

The recent epidemics of sugar-beet yellows and potato virus diseases may have shaken confidence in our ability to control them by conventional methods of crop hygiene and chemical sprays, but it has stimulated laboratory and glasshouse studies to find other ways of controlling virus spread. Progress has been made in the technique of using isolated protoplasts for studying virus multiplication (p. 243), and the characterisation of the helper component in sap that aphids need before they can transmit virus offers new hope of controlling virus spread (p. 243). Insect-trapping hairs, found originally on the foliage of three wild potato species have been introduced into hybrids with the cultivated potato and by preventing aphid movement promise to be a new method of biologically controlling virus spread (p. 271), although the value of this method of control still needs to be established under field conditions. Our lack of recent work on potato blight does not reflect complacency, but merely that the pattern of weather has kept our crops free from blight since 1968 and so we have deployed our efforts to more urgent problems, of which there are many.

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Properties of viruses and virus diseases

Mechanism of infection of tobacco protoplasts with TMV. To infect tobacco protoplasts we normally use an inoculum containing 1 μg TMV ml^{-1} and 2 μg poly-L-ornithine (PLO) ml^{-1}. The concentration of TMV can be decreased to one-tenth without decreasing percentage of infection or yield of virus but a similar decrease in concentration of PLO prevents infection. However, a normal mixture of TMV and PLO which has been incubated for 10 min can then be diluted to one-tenth without decreasing infection. PLO at 2 μg ml^{-1} is adsorbed on the virus causing aggregation and precipitation, and the precipitate is highly infective after sedimenting at 9000 **g** and resuspending in fresh buffer solution. Scanning electron microscopy shows that PLO causes wounds on the plasmalemma through which the virus probably enters the protoplasts, and this would explain why PLO absorbed on the virus causes most infection. (Kassanis, White, Woods and Turner)

Transmission component for potato virus Y (PVY). We have continued to characterise the helper component in sap that aphids need before they can acquire PVY from pure solutions. Activity of the component was stabilised by magnesium but not sodium ions; neither restored activity to inactive preparations. Little activity was lost by storage at −20°C for several days, but activity was destroyed by pronase or trypsin, suggesting that the component is a protein. Crude preparations were fractionated on Sephadex columns but even the most active fractions still gave many protein bands when analysed by electrophoresis on polyacrylamide gels. The component did not adsorb to either of the resins DEAE-cellulose or DEAE-Sephadex in the presence of 0·01M $MgCl_2$ or to carboxymethyl cellulose.

No PVY protein was detected serologically in highly concentrated preparations of the component. This, and the fact that 0·01M $MgCl_2$ extensively aggregated PVY protein, indicate that the helper component is not composed of PVY protein. Further, its activity was neutralised by antiserum prepared against helper component but not by antisera prepared against PVY protein or PVY inclusion body protein. Unlike poly-L-ornithine, which enables tobacco mosaic virus to be transmitted by aphids, the PVY helper component was not rapidly removed from aphid stylets when they probed sucrose solutions, suggesting that the action of the two is different. (Govier, Kassanis and Pirone)

Beet yellows virus (BYV). The infectious single stranded RNA of Beet Yellows Virus (*Rothamsted Report for 1974*, Part 1, 213) was isolated from purified virus and its properties studied. RNA obtained by two-phase phenol extraction in the presence of 0·005M EDTA and 0·1% SDS was similar to that obtained by freezing the virus in the presence of 2M LiCl which disrupts the particles and precipitates the RNA. It was essential to keep the preparations at −20°C for at least 3 h; brief freezing gave low yields and mere admixture with the salt at room temperature or 4°C gave none. To avoid nuclease degradation of the RNA the virus was usually treated with bentonite. Yields of 50–70% were obtained from about 4 mg virus. The ratios of u.v. extinctions 260/280 nm and 258/230 nm (max/min) both lie in the range 2·0–2·2 and show that the RNA is essentially free of protein.

In 0·1M phosphate buffer pH 7·0, the bulk of each preparation sedimented at 46S. Slower sedimenting components were present but these varied in amount and sedimentation coefficient and were frequently heterogeneous in size. They probably originated from broken virus particles and by degradation during isolation. Using the empirical equation of Spirin, 46S corresponds to a molecular weight (mol. wt.) of $4{\cdot}8 \times 10^6$. To obtain a more reliable size estimate the sedimentation coefficient of formaldehyde-

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treated RNA (in which tertiary structure is eliminated) was determined (Boedtker, *Journal of Molecular Biology* (1968) **35**, 61–70). Most of the RNA now sedimented at 17·4S, equivalent to mol. wt. $2{\cdot}25 \times 10^6$, although a proportion sedimented at 22S, mol. wt. $4{\cdot}05 \times 10^6$. Boedtker suggested that a similar change with TMV–RNA was due to the unmasking of hidden breaks as the hydrogen bonds were disrupted.

From the electrophoretic mobility of BYV–RNA on agarose–acrylamide gels we calculate a mol. wt. of $4{\cdot}8 \times 10^6$. The agreement between these three size estimates is remarkably good in view of the limitations of the methods, particularly as all require extrapolation from characterised RNA's of much smaller mol. wt. Thus the genome of BYV consists of a single RNA strand large enough to code for about 20 proteins; one of the largest messengers characterised. Its size is similar to the RNA of the plant rhabdovirus lettuce necrotic yellows (mol. wt. 4×10^6) but larger than any from viruses of similar morphology. (Carpenter, Kassanis and White)

Structure of cucumber mosaic virus. The two strains of cucumber mosaic virus maintained at Rothamsted differ considerably in the ease with which they are transmitted by aphids. On SDS-acrylamide gel the protein of the easily transmitted strain shows a single component, the mol. wt. about 26 000 agreeing closely with that found by van Regenmortel *et al.* (*Virology* (1972) **49**, 647–653). Particles of the poorly transmitted strain contain a similar proportion of protein whose subunit size is double that of the other strain. This unique result, confirmed with carboxymethylated protein where aggregation is unlikely, suggests that particles of the poorly transmitted strain contain only 90 protein subunits instead of the 180 proposed by Finch *et al.* (*Journal of Molecular Biology* (1967) **24**, 303–305) and have a structure not encompassed by the quasi-equivalence theory for isometric viruses (Caspar & Klug, *Cold Spring Harbor Symposium on Quantitative Biology* (1962) **27**, 1–24). (Carpenter)

Cryptic virus of sugar-beet plants. In 1966, Pullen found that sugar-beet plants (*Beta vulgaris* L.) and plants of other *Beta* spp. contained spherical, virus-like particles which were seed-borne. She was unable to transmit the virus to other plant species (*Rothamsted Report for 1966*, 110; *for 1967*, 124; and *for 1968*, 127). We are investigating this virus which was named 'cryptic virus' as it causes no symptoms. Seventeen sugar beet plants of each of the varieties Camkilt, Nomo and Sharpe's Klein E were examined and about 10% were virus-free; the rest differed in the concentration of cryptic virus they contained. These virus-free plants were propagated by cuttings to produce virus-free seed. The plants remained free of virus throughout the growing season. We were unable to transmit the virus to healthy sugar beet by mechanical inoculation or by dodder.

Virus in infected plants is in low concentration and tends to become insoluble during purification. It was purified by extracting leaves in 0·5M phosphate buffer containing 1% ascorbic acid at pH 8, stirring the extract with an equal volume of a butanol–chloroform mixture (1:1), separating the clarified aqueous phase by centrifuging and stirring it for 30 min with 2·5% Triton X-100. The virus was sedimented at 70 000 **g** for 2 h and the pellet resuspended in a small volume of 0·02M tris buffer at pH 8, containing 1% ascorbic acid and 0·01M $CaCl_2$. All operations were done at 20°C. This procedure eliminated ribosomes and most other proteins and minimised virus losses from insolubility. (Kassanis, White and Woods)

A virus disease of *Spartina* sp. Negatively stained preparations from mottled leaves of *Spartina townsendii* H. & J. Groves, revealed flexuous rods 750–800 nm long. Pinwheels and laminated inclusion bodies were observed in thin sections of affected mesophyll cells. The virus, although morphologically similar to viruses of the PVY group, was not

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transmitted mechanically or by aphids to a range of local lesion hosts, or to suspected systemic hosts in the Gramineae. The virus has been found in *S. anglica*, *S. alterniflora* and *S. glabra* as well as *S. townsendii*, and is widely distributed from Spurn Head, Yorkshire, round the south coast to Bridgwater Bay, Somerset. (Jones and Dabek)

Virus diseases of tropical crops

***Viruses of taro* (Colocasia esculenta).** Plants affected by alomae disease contain bacilliform particles of two different sizes (Kenten & Woods, *PANS* (1973) **19**, No. 1, 38–41). When we were using test plants, vegetatively propagated from taro grown in the Solomon Islands and possibly virus-infected, alomae disease was transmitted by the delphacid plant hopper *Tarophagus proserpina*. Recently, when we have used virus-free test plants raised from seed, *T. proserpina* transmitted only the larger particle and the plants were not killed. The smaller particle was transmitted, though inefficiently, by the mealybugs *Planococcus citri* and *Pseudococcus longispinus*. Mealybugs are not always found where alomae occurs and so it seems that as a result of mealybug transmission and vegetative propagation the small particle may be latent in all alomae-susceptible cultivars. Subsequent infection by the large particle, transmitted by hoppers, may stimulate multiplication of the smaller particle and result in lethal alomae. Thus, virus-free stocks of taro, if established on Malaita, will need protection against both mealybugs and hoppers. No alternate hosts of the bacilliform taro viruses have been found among a wide variety of crops and weeds with viral symptoms close to alomae-infected plots. (Dabek and Plumb, with Mr. D. E. Gollifer and Dr. G. V. H. Jackson, Solomon Islands)

***Pathogens of sweet potato* (Ipomoea batatas) *in the Solomon Islands*.** Witches' broom and chlorotic little leaf symptoms (WBCLL) occurred on only one of five cultivars observed on Guadalcanal, Solomon Islands, and we are trying to discover whether the other four are resistant or whether the means of spread are absent. Mycoplasma-like organisms (MLO) have been found consistently in plants with WBCLL symptoms but not in symptomless plants. Long-rod virus particles are frequently but not always found, with the MLO, in the susceptible cultivar. They are straight or slightly flexuous rods seemingly 650–900 nm long, but fragmentation and aggregation preclude more definite measurements. Relationships of the virus are unknown.

At present there is no witches' broom of sweet potato on Malaita, although MLO have been discovered in a 'weed variant' of *Ipomaea batatas* with similar symptoms. Because the WBCLL-susceptible cultivar is also grown in Malaita, we are trying to determine whether the MLO of Guadalcanal and Malaita are related. (Dabek)

***Macana disease* (*chlorotic streak*) *of* Furcraea *spp*.** Macana, a disease of the fibre 'fique' plant (*Furcraea* spp. (Agavaceae)) now prevalent in Colombia, South America, is characterised by acropetal chlorotic leaf streaking and necrosis affecting leaves of all ages. Studies at the Commonwealth Mycological Institute and in South America have failed to reveal fungi or bacteria as potential causal agents.

Preparations of chlorotic leaf tissue contained spherical virus-like particles *c.* 30 nm in diameter; the severity of streaking was related to particle numbers. No particles were found in healthy plants, so macana is probably caused by a virus. Ultrathin sections showed virus in epidermal and mesophyll cells as individual particles, in groups or chains, and as paracrystalline arrays in membrane-bound vesicles, which were sometimes 'embedded' in amorphous matrices.

To purify the virus, infected tissue was ground in water, the extract filtered through muslin and clarified with 10% butanol and low-speed centrifugation. Virus was pelleted

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by high-speed centrifugation and resuspended in 0·01M potassium phosphate buffer, pH 7. The single component had a sedimentation coefficient of 124S and yields of virus were estimated to be 100–125 mg kg^{-1} of fresh tissue. (Dabek, with Dr. I. A. S. Gibson and Mr. J. M. Waller, C.M.I.)

Oil palm viruses. A rod 600 nm long and a sphere 30 nm in diameter, apparently virus particles, were found in oil palm pinnae sent from Papua New Guinea. The initial samples were associated with a disorder called white stripe, but subsequently particles have been found equally in striped and unstriped samples. The particles have not been found in samples from the Solomon Islands and Malaysia. Seedlings grown at Rothamsted from New Guinea seed appeared healthy and contained no particles. The particles have not been transmitted manually to any of the usual test plants. (Plumb and Dabek, with Dr. Shaw, Department of Agriculture, Stock and Fisheries, Papua New Guinea)

Mycoplasma-like organisms (MLO) associated with Kaincope disease of coconut in Togo. MLO occurred in a few sieve tube cells of juvenile leaves from a diseased coconut palm. Only 10–15% of the vascular bundles examined were affected. The fact that no virus, fungi, bacteria or rickettsia were observed in diseased tissue and that no MLO have yet been located in healthy coconut phloem suggest that MLO are the causal agents of Kaincope. (Dabek, with Dr. C. G. Johnson, ODM Consultant and Mr. H. C. Harries, Coconut Industry Board, Jamaica)

Biodeterioration

Deterioration of agricultural produce in storage can be an important source of crop loss, affecting not only quantity but also quality. Many moulds that spoil stored products such as grain and hay produce spores that are capable of causing diseases in man and animals by allergy or infection and some fungi produce toxic metabolites. Our work is concerned with identifying these moulds, the sources from which they come, and the conditions of storage that favour their activity. The work involves cooperation with other Agricultural Research Institutes, and with medical and veterinary research. (*Rothamsted Report for 1973*, Part 1, 119–122)

Moulds of cereals

During ripening. Unlike previous years, yield of spring barley grain, 1000 grain weight and germinability were not significantly improved by controlling mildew with tridemorph nor by one to three benomyl sprays during the eight weeks prior to harvest. Although yields following the extremely dry summer were less than two-thirds of normal, and grain at harvest was unusually dry the surface microflora was similar to other years both numerically and in the range of species represented. Three sprays of benomyl affected yeast numbers little but decreased numbers of fungi by 50% or more (Table 1).

TABLE 1

The effect of timing and number of benomyl sprays on surface fungi, excluding yeasts, of barley grain at harvest

Mildew control	Timing of benomyl sprays*							
	O	E	M	L	EM	EL	ML	EML
	(10^5 propagules g^{-1} dry wt. of grain)							
none	101	60	84	73	78	79	44	50
tridemorph	114	86	48	63	78	53	49	44

* O, no spray; E, 16 July; M, 28 July; L, 11 August. Harvested on 22 August 1975

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Moulds potentially important in storage were again isolated from barley grain at harvest and included *Aspergillus candidus*, *A. fumigatus*, *A. repens*, *A. versicolor*, *Penicillium piceum*, *P. hordei*, *P. roqueforti* and *P. cyclopium*.

During storage. Spontaneous heating of grain harvested in 1974 occurred only when its initial water content exceeded 22% since few immature grains were present. Moulding was slight in grain stored with 16·5% water initially (Table 2) but mouldiness greatly increased and germinability was lost after five months' storage with more than 22% initial water. Up to 75×10^6 propagules g^{-1} dry weight of grain of the thermoduric *Penicillium piceum* and 10^6 propagules g^{-1} of *P. capsulatum* were present in grain that had heated to 51°C.

TABLE 2

Effect of different water contents on maximum temperature, germinability and mycoflora of barley grain during nine months' storage

Initial water content %	Maximum temperature °C	Germination %	Total fungi (10^6 propagules g^{-1} dry wt.)	*Penicillium* spp. (10^6 propagules g^{-1} dry wt.)	Predominant *Penicillium* spp.
27·0	51	0	328	81	*P. piceum*, *P. capsulatum*
22·3	36	0	85	77	*P. cyclopium*, *P. rugulosum*, *P. hordei*
21·1	21	10	22	18	*P. cyclopium*
17·5	19	67	4	1	*P. cyclopium*
16·5	19	89	3	<0·1	

A single linkage cluster analysis of the occurrence of different species showed that the presence of *P. piceum* was strongly linked to the occurrence of *Aspergillus flavus*, *A. fumigatus*, *A. nidulans*, *Absidia* spp. and *Humicola lanuginosa*. *P. cyclopium* was associated with *Aspergillus versicolor* and became dominant in grain stored at 22% water, in which *P. hordei* and *P. rugulosum* reached their largest numbers. Species of the *Aspergillus glaucus* group became most numerous when the water content was less than 20% and *A. candidus* at 23·5%. (Hill and Lacey)

Prevention of moulding in damp hay. Although we found that more propionic acid was required to prevent moulding as the water content of hay increased (*Rothamsted Report for 1967*, Part 1, 129), there seemed no simple relationship between the amount of acid needed and water content. However, over a range of water contents from 25 to 50%, heating and moulding almost always occurred if the ratio of water in the hay to propionic acid exceeded 100 : 1·2. If the ratio was less, heating was rare (twice in more than 40 tests). In field trials when the distribution of acid within bales was good, there was a similar relationship between the amount of water, the amount of propionic acid retained, and moulding of the hay.

Interactions between *Paecilomyces varioti* and propionic acid (*Rothamsted Report for 1974*, Part 1, 159) were studied in pure culture using malt extract agar or broth. Free acid added to the cultures prevented growth more than anticipated from tests with hay, probably because hay exerts a greater buffering capacity than the culture media. When ammonium propionate was substituted for propionic acid, results in culture resembled those in hay with both propionic acid and ammonium propionate.

Non-sterile hay treated with small, ineffective amounts of propionic acid sometimes develops moulds other than *P. varioti*. Eight fungi isolated from such hay showed varied abilities to grow on and degrade propionic acid. Of four members of the *Aspergillus glaucus* group, one isolate of *A. chevalieri* tolerated a maximum concentration of 0·4%

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propionic acid, another 0·2%, while single isolates of *A. amstelodami* and *A. repens* tolerated only 0·1%. An unidentified yeast tolerated 0·4% propionic acid, single isolates of *Absidia corymbifera* and *Scopulariopsis brevicaulis* 0·2%, and *Fusarium culmorum* only 0·1% propionic acid.

The limitations of propionic acid as a hay preservative led us to seek alternative chemicals. Each substance was incorporated, as 0·5% of active ingredients, in hay containing 35% water. The hay was kept in small jars at 25°C or in 4-litre Dewar flasks at room temperature and allowed to heat spontaneously. The jars were examined weekly for moulding. Temperatures in the flasks were recorded daily for at least one month and the hay examined for moulding at the end of the test. Over 60 substances, including a number of established fungicides, were tested, but few delayed moulding sufficiently to warrent further investigation. Long and short chain amines were ineffective although ammonia restricted fungal growth but apparently encouraged farmer's lung actinomycetes. A number of phenols and substances related to propionic acid were effective, including isomers of butyric and pentanoic acids, phenyl propionate, tripropionin and ammonium propionate. Although the activity of ammonium propionate differed little from propionic acid, it was examined in more detail because it is less volatile, less corrosive, more pleasant and safer to handle. In field trials, ammonium propionate was slightly less effective than the free acid, but more ammonium salt was retained in the hay. Thus, in terms of the amount of propionic acid used, the free acid and its ammonium salt were similarly effective in preventing heating. (Lacey, with Lord and Manlove, Chemical Liaison Unit, and Mr. R. Charlick, NIAE)

Measuring the effects of plant diseases

In 1973 we began to investigate how foliage and root pathogens of cereals affect plant activity, and to find ways of measuring this so that we might understand better how diseases affect yield (*Rothamsted Report for 1973*, Part 1, 122–124). Mildew was used as an example of a foliar disease and take-all as a root disease; but the effects of some other root-infecting fungi have also been studied.

Effects of barley mildew (*Erysiphe graminis*) on host metabolism. A radioactive tracer $^{14}CO_2$ was used in a field experiment with winter barley to estimate the contribution of the second and third youngest leaves to C in the ear and the influence of powdery mildew infection on C assimilation and translocation.

Twenty-four hours after supplying second youngest leaves of plants at ear emergence with $^{14}CO_2$, those on which mildew had been controlled by two tridemorph sprays contained 100% more and those sprayed once 75% more total radioactivity than unsprayed plants. The area of the fed leaf affected by mildew on untreated plants and those sprayed once or twice was respectively 25, 3 and 0%. The presence of mildew led to even greater differences in the content of ^{14}C within the ear; once sprayed contained 150% more and twice sprayed 250% more radioactivity than the control. At this growth stage very little ^{14}C was fixed by the third leaf, and almost none of this passed to the ear. There were no differences in total radioactivity between treatments. (Finney and Bainbridge, with Thorne, Botany Department)

Powdery mildew also induces premature senescence of infected leaves characterised by a rapid loss of chlorophyll from the leaf after sporulation of the fungus, at a rate equal to that in detached leaves. This is accompanied by an increase in α-amino nitrogen content while protein content remains relatively stable. (Finney)

Effects of root-infecting fungi on transport of materials by young wheat plants. In

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take-all development a crucial stage is the invasion and disruption of the phloem by hyphae leading to a breakdown of the ion uptake mechanism (Clarkson, Drew, Ferguson, Sanderson, *Physiological Plant Pathology* (1975) **6**, 75–84). Recent work shows that other root-infecting fungi do not block the phloem and therefore affect ion uptake less, since photosynthetic assimilates can still be transported to the sites of uptake.

Uptake and translocation of nutrients. Nutrient uptake by plants grown in infested sand was measured on the 33rd day by feeding radiotracers (^{32}P, ^{42}K, ^{45}Ca) and the cumulative effect of the preceding 32 days obtained by determining the total P, K, Ca and Mg in roots and shoots. Compared with healthy plants, those infected with *Gaeumannomyces graminis* (87% of root axes lesioned) took up and translocated less P and K g^{-1} dry weight of root, but when all healthy roots were amputated there was still some uptake and translocation of P and K. By contrast, infection slightly increased uptake and translocation of Ca, possibly because this ion moves by a different radial pathway through the root. Estimates of the cumulative translocation efficiency (μmol ion in the shoot g^{-1} root dry weight) of infected plants on the 33rd day were greater than those for healthy plants. This was also true for plants infected by *Aureobasidium bolleyi* (43% axes lesioned), *Cochliobolus sativus* (80% axes lesioned) and *Fusarium culmorum* (86% axes lesioned). All infections decreased the total plant dry weight.

TABLE 3

Distribution of ^{14}C in wheat plants with root infections

	Experiment 1				Experiment 2		
	% In shoots	% In crown roots	% In seminal roots		% In shoots	% In crown roots	% In seminal roots
Uninfected	76·0	9·2	14·8	Uninfected	77·6	20·7	1·7
G. graminis	84·7	15·1	0·2	*A. bolleyi*	80·4	19·6	0·0
SED (9 df)	4·86	3·84	3·04	*C. sativus*	84·2	10·5	5·3
				F. culmorum	89·8	7·0	3·2
				SED (9 df)	2·64	2·46	1·85

Distribution of photosynthetic assimilates. All root infections increased the proportion of ^{14}C retained after 24 h in the shoot of 33-day-old plants whose leaves received a 10 min exposure to $^{14}CO_2$ (Table 3). In autoradiographs seminal root axes infected with *C. sativus* and *F. culmorum* were labelled along their whole length, whereas *G. graminis* blocked translocation into the seminal roots, which remained unlabelled, and ^{14}C accumulated in the crown roots. *A. bolleyi* killed the seminal roots at an early stage, so they contained no ^{14}C. (Fitt and Hornby)

Silicon uptake as a measure of root damage. Last year we reported that infection of wheat roots by take-all greatly decreased the amount of silicon in the glumes on a dry matter basis (*Rothamsted Report for 1974*, Part 1, 219). Hutton and Norrish (*Australian Journal of Agricultural Research* (1974), **25**, 203) showed that the silicon content of wheat glumes was related to the amount of water transpired. As root disease restricts water uptake during grain formation silicon content might provide another method of assessing effects of disease on root activity. During 1975 more samples of glumes collected at harvest in 1973 were analysed by X-ray fluorescence spectroscopy.

Table 4 shows the grain yields and percentage of silicon in the glumes of seven winter wheat cultivars grown on two contrasting sites, a 'healthy' site under crop rotation and a 'diseased' site previously cropped with cereals. The strikingly low silicon content reflects the high incidence of take-all on the 'diseased' site and probably resulted from a restricted

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TABLE 4

Yield of grain and silicon content of glumes of winter wheat cultivars at Rothamsted, 1973

	Healthy site		Diseased site	
Cultivar	Grain, t ha^{-1}	Si, % of dry matter	Grain, t ha^{-1}	Si, % of dry matter
Cappelle	5·24	4·6	4·44	1·4
Atou	7·32	4·4	4·88	1·6
Bouquet	6·29	4·6	4·57	2·0
Maris Freeman	7·38	4·4	4·72	1·6
Maris Huntsman	8·75	4·5	5·15	1·8
Maris Nimrod	7·92	4·4	5·55	1·8
Maris Widgeon	6·09	5·0	4·08	1·9

water uptake. It was not possible to confirm this by measuring water extraction by the crops on the two sites, but in an experiment at Woburn there was a strong correlation between water extraction by healthy and diseased crops, and the silicon content of their glumes.

On Broadbalk, where previous cropping and long-term fertiliser treatments give large differences in winter wheat yield, take-all symptoms on the roots are not usually prevalent or severe. The silicon contents shown in Table 5 are comparatively large, suggesting little effect of disease on water extraction (root activity), and the low yields can be attributed mainly to fertiliser deficiencies. In the second wheat crop after fallow on plot 10 a patch of plants with severe take-all was associated with phosphate deficiency and showed the usual depression in silicon content. (Salt and Rushforth)

TABLE 5

Analysis of wheat glumes, Broadbalk 1973

			Element				
	Plots		K	S (% of dry matter)	P	Si	Yield t ha^{-1}
1st wheat after fallow	5/3	No fertiliser	0·49	0·09	0·11	5·15	3·69
	5/5	Mineral −N	0·30	0·07	0·07	5·55	4·14
	5/8	Minerals +N	0·53	0·13	0·13	4·19	4·62
	5/10	Minerals −P +N	0·54	0·11	0·11	4·50	5·47
2nd wheat after fallow	6/3	No fertiliser	0·46	0·09	0·13	5·23	1·05
	6/5	Minerals −N	0·44	0·09	0·13	5·06	1·30
	6/8	Minerals +N	0·56	0·12	0·11	3·38	5·46
	6/10	Minerals −P +N	0·46	0·10	0·08	3·38	3·14
	6/10	+Take-all	0·53	0·12	0·06	1·67	—
Continuous wheat	9/3	No fertiliser	0·42	0·08	0·09	4·22	1·43
	9/5	Minerals −N	0·37	0·08	0·09	4·14	2·04
	9/8	Minerals +N	0·52	0·12	0·14	3·57	5·74
	9/10	Minerals −P +N	0·38	0·12	0·08	3·42	2·60

Cereal diseases

Barley yellow dwarf virus (BYDV). All the principal aphid species that transmit BYDV were more numerous than in 1974, and many more were vectors; 11% of alate *Rhopalosiphum padi*, 3% of *Macrosiphum* (*Sitobion*) *avenae*, 5% of *Metopolophium dirhodum* and 2% of *M. festucae* transmitted BYDV to test plants. *R. padi* were more prevalent in the spring and summer than usual but autumn migrants were very few, so despite much early drilling it seems unlikely that BYDV infection will be extensive on winter-sown cereals in 1976.

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Wet conditions resulted in late sowing in autumn 1974 of oats and wheat and a wide range of sowing dates, from late February to late April, of spring barley. Insecticides applied at sowing or the following spring had no effect on virus incidence or yield of autumn sown crops, but spring wheat and spring oats sown interspersed in autumn sown crops yielded 10–12% more (0·4–0·5 t ha^{-1}) when phorate was applied at sowing. Spring barley sown at a similar time (early March) did not respond to this treatment. Barley sown in early March was less than 5% infected in July, but that sown in late April had ten times as many infected plants. (Plumb)

Because BYDV was widespread, many samples were collected or received for diagnosis. In addition, we received samples collected by the Agricultural Development and Advisory Service as part of a survey of viruses in perennial ryegrass. All of the cereal samples were infected with isolates of BYDV transmitted by *R. padi* and many were severe. A third of the grass samples was infected and *R. padi* was again the principal vector. (Lennon and Plumb)

Powdery mildew (*Erysiphe graminis*) on barley. The difficult spring delayed sowing of many experiments at Rothamsted, and, as expected, mildew was more severe in the later than in earlier sown experiments.

Effects on yield. Plots of spring barley (cv. Zephyr, sown 23 April) in which mildew was controlled with tridemorph sprays showed a greater response to increasing amounts of applied nitrogen than did untreated plots. The best yield (4·45 t ha^{-1}) was obtained from tridemorph-treated plots given the maximum amount of nitrogen tested (135 kg ha^{-1}) to the seedbed, but the results did not indicate whether mildew affected the optimum dressing. Plots given nitrogen late, as a top dressing, yielded less than those given nitrogen to the seedbed, but tridemorph increased yields similarly whether nitrogen was applied early or late.

To investigate the effects of mildew on utilisation of applied nitrogen, crop samples taken before ear emergence were used to estimate nitrate concentrations in the stem bases. Concentration was increased by extra nitrogen but the effect of disease was inconsistent. (Jenkyn and Finney)

Spray-timing experiment. In an experiment using cv. Julia, designed to test the effects of mildew in the surrounding crop on response to single tridemorph sprays (applied on seven dates between 22 May and 20 June), blocks were either surrounded by Julia treated with ethirimol seed dressing and sprayed with tridemorph or by untreated Julia. Mildew did not become severe in this experiment and differences in reinfection of early-sprayed plots according to surround did not develop until late. The first spray on 22 May gave the best yield (5·55 t ha^{-1}), somewhat surprisingly as it was applied at growth stage 3 (tillers formed) before mildew was observed in the crop and more than two weeks before spore catches on sticky rods above unsprayed plots first exceeded 100 spores cm^{-2} day^{-1}. (Jenkyn, Bainbridge and Vine)

Insensitivity of* E. graminis *isolates to ethirimol. Plots of spring barley (cv. Proctor) treated or untreated with ethirimol seed-dressing (0·007 g a.i. g^{-1} seed) were either uninoculated, inoculated with an ethirimol-sensitive isolate or inoculated with an ethirimol-insensitive isolate. Throughout the season mildew samples were tested for sensitivity to ethirimol by inoculating seedling leaves of barley, dipped 2 h previously in a range of ethirimol concentrations (0–125 μg ml^{-1}) in aqueous solution. By this method relatively large differences in sensitivity can be detected, but the data obtained are often variable and more critical analysis is difficult.

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Airborne inoculum from outside the experiment was often ethirimol-insensitive, consequently a moderately insensitive population was rapidly established on uninoculated plots. Average LD50 values for the season were 2·6 μg ml^{-1} on untreated plots and 5·1 μg ml^{-1} on ethirimol-treated plots. When the treated plots were inoculated with the sensitive isolate, the average LD50 was 5·4 μg ml^{-1}. On plots inoculated with the insensitive isolated the LD50 values remained high throughout the season, averaing 9·3 and 10·2 μg ml^{-1} on plots with and without ethirimol, respectively. However, on the untreated plots inoculated with the sensitive isolate the LD50 values remained low, averaging 1·3 μg ml^{-1}.

These results suggest that the sensitivity of the mildew population present in plots through the season was determined by that of the initial inoculum. (Janet Smith and Bainbridge)

Effect of fungicides on spring wheat (cv. Kleiber). Yields were limited by late sowing (25 April) and summer drought, and untreated plots yielded only 2·77 t ha^{-1}. Mildew was the most prevalent disease (*c.* 10% on second youngest leaves at growth stage 11.1) and neither brown nor yellow rust were significant. Two sprays of triadimefon increased yield to 3·24 t ha^{-1} but seed treatment, which decreased emergence by 25%, plus one spray of triadimefon increased yield to only 2·90 t ha^{-1}. Two sprays each of benodanil, tridemorph or carbendazim had little effect on yield although the tridemorph controlled mildew. (Jenkyn and Bainbridge)

Spore dispersal and deposition

Deposition of particles in cereal crops. Spores are deposited on plant surfaces both by impaction and sedimentation. The efficiency of impaction increases with increasing wind speed whereas sedimentation is greatest when the air is still. It is not known which of these two processes predominates when mildew spores are deposited in cereal crops, where wind speeds are normally less than 50 cm s^{-1}.

Collection efficiencies of vertical and horizontal barley and wheat leaves was estimated by dispersing fluorescent, polyethylene glycol in mature crops using a spinning-disc aerosol generator. The number of droplets caught by leaves was counted using the Quantimet image analyser.

For the droplet size equivalent to *Erysiphe* spores, the upper surfaces of horizontal leaves caught ten times more droplets than did vertical leaves. Sedimentation thus seems likely to be the chief deposition process for mildow spores within crops; only at the very top of the crop is impaction likely to be more important. (Bainbridge and Stedman)

***Dispersal of spores of* Rhynchosporium secalis.** Modified rotorods (*Rothamsted Report for 1974*, Part 1, 222) were used to trap *R. secalis* spores in a plot (4 m^2) of Maris Otter winter barley. The plot was in the middle of a 0·1 ha stand of February-sown barley of the same variety. Six traps were distributed within the plot at positions approximately 1·5 m apart and at 20-cm intervals between ground level and 120 cm. On 16 rain occasions between early May and mid-June most spores were found on the trap at ground level; very few spores were trapped at 40 cm and above.

In the same plot, six pots (12 seedlings per pot) of healthy Maris Otter barley were exposed at random sites and changed after each rainfall occasion. The pots were sunk into holes so that the plants were at ground level, three were surrounded by wire mesh guards to prevent contact with the adjacent crop and to stop water dripping or running on to the healthy seedlings. After exposure the seedlings were removed and isolated until lesions of *R. secalis* could be counted. On three of 32 rain occasions between early May

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and late July no lesions developed, and on only four occasions most lesions developed on guarded plants. On the other occasions the ratio of lesion number between guarded and unguarded plants varied considerably when few lesions developed, but on four of the five occasions when infection was considerable 60% more lesions were counted on unguarded plants. The transfer of water between plants by contact, dripping or run-off appears to be an important method of spore dispersal.

The plot of infected barley surrounded by the larger area of initially healthy crop provided an opportunity of measuring dispersal gradients from a small area source. During the last week of July, samples each of 50 tillers, were taken at similar distances outward from each side of the central square plot. Close to the source samples were 0·5 m apart but beyond 5 m they were 2·5 m apart. The samples were washed and spore counts were used as a measure of infection. Between the crop edge and 0·5 m spore numbers decreased by 80% and between 0·5 and 1 m by 40%. Thereafter the decrease was slower, and at 7·5 m the spore count was 1·5% of the count on the crop edge. Exposed seedlings had indicated 29 infection occasions from early May, but more had certainly occurred since the surrounding crop had emerged in early April. The steepness of the gradient supports indications from previous work that most splash dispersed spores travel only short distances in cereal crops. (Stedman)

Eyespot on winter wheat varieties. In 1974 the grain yield on the semi-dwarf wheat Maris Fundin (7·34 t ha^{-1}) ranked equal first of eight varieties grown after potatoes, but ranked eighth (5·36 t ha^{-1}) after barley. Eyespot 'straggling', caused by *Cercosporella herpotrichoides*, seemed more common in Maris Fundin than in other varieties, but results from the few routine samples taken to estimate foot and root rots did not confirm that Maris Fundin was exceptionally susceptible to eyespot (Table 6). In 1975 a similar variety trial was more intensively sampled, the fungicide carbendazim having been applied on 15 May, growth stage 5 to 6, at 0·25 kg a.i. ha^{-1}. Table 6 shows that Maris Fundin had more plants and shoots infected than other varieties on 13 May, but differences were not very large. However, lesions on Maris Fundin had penetrated more deeply than on other varieties, which may explain why more infection persisted through the dry summer—conditions unfavourable to eyespot. Carbendazim decreased eyespot on all varieties, but increased yield considerably (0·6 t ha^{-1}) only on Maris Fundin. These results confirmed that Maris Fundin is more susceptible to damage by eyespot than previously suspected, and suggest that methods used to assess varietal susceptibility to *C. herpotrichoides* may need improving. (Slope, Gutteridge and Jenkyn, with Moffitt, Farm)

TABLE 6

Percentage eyespot on winter wheat varieties grown after barley

	July 1974	May 1975		July 1975	
	% Straws	% Plants	% Shoots	% Straws	
				Without carbendazim	With carbendazim
Atou	72 (44)*	52	24	22 (3)	1 (0)
Bouquet	68 (40)	45	17	28 (7)	1 (0)
Cappelle-Desprez	43 (15)	45	23	22 (6)	1 (0)
Flinor	—	45	25	16 (4)	1 (0)
Maris Freeman	61 (31)	47	23	19 (3)	1 (0)
Maris Fundin	64 (42)	56	34	55 (30)	7 (2)
Maris Huntsman	60 (30)	31	12	23 (2)	2 (0)
Maris Nimrod	62 (32)	—	—	—	—
Maris Templar	59 (33)	45	21	16 (3)	2 (0)

( )* Moderate and severe symptoms

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Take-all and other root infecting fungi

Effects of phosphate fertiliser on take-all of wheat. From 1960 the three series of the Residual Phosphate experiment were cropped in rotation with swedes, potatoes, barley, but successive winter wheat crops are now grown after the last barley on each series. We reported last year that the first wheat after barley on Series III was severely attacked by take-all, *Gaeumannomyces graminis*, only where P was lacking (*Rothamsted Report for 1974*, Part 1, 224). In 1975 all the second wheat crops on this series were damaged by take-all, though it was least severe and yields largest on soils rich in P. In contrast, the first wheat after barley on Series II was only lightly attacked by take-all, and grain yields were much larger than the best yields on Series III, even where P was lacking (Table 7). These results suggest that generous use of P fertiliser may delay and mitigate, but not prevent, damage by take-all. (Slope and Gutteridge, with Mattingly, Chemistry Department)

TABLE 7

The effect of phosphate fertiliser on take-all and yield of winter wheat, Residual Phosphate experiment, Sawyers 1975

P manuring, kg P ha^{-1}		Series II 1st wheat after barley			Series III 2nd wheat after barley		
		Take-all			Take-all		
		% plants	July rating*	Grain, t ha^{-1}	% plants	July rating	Grain, t ha^{-1}
Nil		33	56	5·34	95	208	1·85
Annually	12	24	29	6·43	94	212	1·93
	25	10	15	6·39	81	168	2·48
	50	8	17	6·54	86	188	2·78
	75	4	4	6·77	77	158	3·18
Triennially (last, autumn 1974)	38	19	28	6·60	95	210	1·97
	75	15	24	6·60	86	180	2·31
Every 6 years (last, autumn 1972)	150	12	18	6·11	77	170	2·94
	300	15	25	6·40	90	197	2·91
	450	4	4	6·78	62	119	3·59

All crops received 126 kg N ha^{-1} + 90 kg K ha^{-1}
* Take-all rating = % slight + 2(% moderate) + 3(% severe); maximum score, 300.

The persistence of infectious host residues. In previous Rothamsted reports (1968–72) a lack of detailed knowledge of soil-borne inoculum of *Gaeumannomyces graminis* limited our interpretation of inoculum estimates and the development of an inoculum model. To find how long colonised host residues of different sizes remained intact and infectious, naturally-infested organic debris was extracted after harvest (in 1973 from a spring barley soil and in 1974 from a winter wheat soil) and separated into different size fractions by wet sieving. Samples of soil that had not grown cereals for at least five years (i.e. assumed free from *G. graminis*) were each amended by addition of debris in an amount typical of a cereal-soil and fallowed in the open in concrete pits with free drainage.

Wheat-seedling bioassays in a controlled environment were made on a sample of each soil at the outset and subsequently at monthly intervals. Although coarse debris initially lost infectivity more rapidly than finer fractions, it consistently caused most disease and retained some infectivity for several months after the finer fractions had ceased to be infectious (Table 8). There was again indication of the unexplained midwinter increase in infectivity mentioned in previous reports. The extent to which loss of infectivity can be related to the state of decomposition of the debris is not yet known. Certainly debris retrieved at the end of the second experiment revealed that the coarsest fraction had

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TABLE 8

Persistence of take-all infested debris in soil

Debris: Source	Debris: Nominal size, μm	Infectivity[1]: Start September 1973 Pots[2]	Start September 1973 %[3]	Finish April 1974 Pots[2]	Finish April 1974 %[3]	Last recorded infection
Spring barley 1973	>2000	18	5·5	14	1·7	
	<2000 >707	6	0·2	2	0·2	
	<707 >149	(infective only in October 1973)				
		October 1974		October 1975		
Winter wheat 1974	>4000	30	32	4	0	—
	<4000 >2000	9	1·9	0	0	May
	<2000 >707	9	0·8	0	0	May
	<707 >297	1	0	0	0	March

[1] Complete data up to February 1975 in *EPPO Bull.* (in press)
[2] Number of pots with infection out of 30 tested
[3] % root axes infected in the 30 test pots

almost disappeared, and other extraction experiments have indicated that the relative proportions of debris fractions are not constant. (Henden and Hornby)

Take-all on winter wheat after leys. The continuous winter wheat in the 'phasing-out' parts of the ley–arable experiments became severely attacked by take-all sooner in the lucerne sequence (Lu) than in the grass–clover ley sequence (Lc) on Highfield, and sooner than in either sequence on Fosters. Table 9 shows the severity of take-all in the two wheat crops (1974 and 1975) and the percentage of soil cores, taken from their stubbles, that grew wheat seedlings infected by take-all and *Phialophora*. These results confirmed that *Phialophora* was less prevalent after Lu than Lc on Highfield (*Rothamsted Report for 1974*, Part 1, 225), and showed that the fungus persisted through a potato, wheat, wheat sequence. They also confirmed that there is less *Phialophora* after the Lu sequence on Highfield, once old pasture, than on Fosters, a field with a long history of arable cropping. We cannot yet explain this difference. (Slope, Prew and Gutteridge)

TABLE 9

The occurrence of take-all (GGT) and Phialophora radicicola *var.* graminicola *(PRG) in wheat soils after lucerne (Lu) and grass–clover (Lc) leys, Highfield and Fosters, 1974–75*

	Highfield Lu	Highfield Lc	Fosters Lu	Fosters Lc
1st Wheat 1974				
Crop, take-all rating	3	2	2	4
Soil cores, % GGT	68	10	16	4
% PRG	24	72	92	90
2nd Wheat 1975				
Crop, take-all rating	99	21	22	24
Soil cores, % GGT	92	25	48	29
% PRG	27	88	75	81

Previous crops: leys 1970–72, potatoes 1973

Virus-infected isolates of* G. graminis *var.* tritici *in Barnfield soil. Barnfield carried no cereal crop from 1856 to 1967. From 1968 to 1974 it carried spring barley or spring wheat in alternate years and in 1975 an area was sown to winter wheat as the start of a con-

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tinuous cereal experiment. We have followed the introduction of the take-all fungus into these crops and examined isolates each year since 1972 for virus. From previous experience we did not expect virus in isolates from the first cereal crops and until May 1975 no virus-infected isolates were found, but in July 17 of 38 isolates examined from widely separated plants contained the smaller virus only of the two (27 and 35 nm) we usually find in the take-all fungus. The relatively sudden appearance of virus within three months might indicate either a very efficient vector in soil, a new virus-infected source of take-all inoculum, or that free RNA (unencapsulated), or undetected low amounts of virus were suddenly stimulated to multiply.

Relationship of viruses in* Gaeumannomyces *spp. and* Phialophora *spp. Virus particles were found for the first time in one of 30 isolates of *Phialophora radicicola* var. *graminicola* (PRG) isolated from first wheat after a grass ley on Summerdells. Unlike viruses in *P. radicicola* var. *radicicola* (PRR), *Gaeumannomyces graminis* var. *avenae* (GGA) and *Gaeumannomyces graminis* var. *tritici* (GGT) (isolates from England, Africa, France and the United States) preparations of the 30 nm particles in PRG did not react serologically in gel diffusion tests with antisera prepared against a mixture of the two particles common in GGT or those in PRR. The particles in PRG had sedimentation coefficients of 115S and 79S and in caesium chloride had four components with buoyant densities of 1·294, 1·361, 1·366 and 1·371 g cm^{-3}; all values being different from those for near-similar sized particles in GGT and PRR. Virus particles were found also for the first time in an isolate (G1) of *Gaeumannomyces graminis* var. *graminis* (GGG) from New South Wales, Australia, and similar 35 nm particles were found in an isolate (T1) of GGT from Western Australia. Preparations of both viruses reacted serologically like those from PRR, GGA and GGT above. No virus was found in isolate G5 of GGG from New South Wales or in T2 of GGT from Western Australia. Wong (*Soil Biology and Biochemistry* (1975), **7**, 189–194) has shown that isolates G1 and G5 successfully cross-protect on wheat roots against GGT isolates T2 and T1 respectively and because one isolate of each pair used in cross-protection experiments contains virus it is possible that an indirect virus-related factor is involved in this type of biological control (Rawlinson, *Abstracts 3rd International Congress for Virology, Madrid* (1975), 147). (Rawlinson and Muthyalu)

The* Gaeumannomyces–Phialophora *complex: another perfect state. Moist wheat-seedling roots, colonised by the fungus, PRG (*Rothamsted Report for 1974*, Part 1, 226), produced perithecia and 'pycnidia' after four to six months when kept in alternating light at 15°C and darkness at 10°C. The perithecia have not been described before and we propose to describe them as a new species of *Gaeumannomyces*. However, this has been complicated because recent electron micrographs of the 'pycnidia' suggest that they are in fact mature perithecia in which asci have deliquesced and ascospores have germinated and grown into the disintegrating inner cells of the perithecial wall. Neither perithecia nor 'pycnidia' have been produced in pure or gnotobiotic cultures, but single ascospores and single, filiform 'pycnospores' grew into PRG-like colonies on agar. (Hornby, Slope and Jones)

Diseases in reduced cultivation systems

Winter wheat. Experiments on different cultivation treatments continued in collaboration with the N.I.A.E. The incidence of three soil-borne diseases and the yields from the two winter wheat sites are given in Table 10 as means for the two years 1974 and 1975. Cultivation treatments generally had only a small effect on disease incidence; both take-all and eyespot tended to be less after chisel ploughing or direct drilling than after

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ploughing, but at Boxworth in 1975 the difference was much larger and only 37% straws were infected by eyespot after direct drilling compared with 74% after ploughing. These decreases in disease were not reflected in the yields which were largest after ploughing. In 1974 no foliar diseases were prevalent at either site, but in 1975 yellow rust was severe on Maris Templar at Boxworth (24% area of second youngest leaf infected); there were no differences between cultivation treatments. (Prew)

TABLE 10

Effects of cultivations on soil-borne diseases and yields of winter wheat (means of different secondary cultivations and of two years 1974, 1975)

	Boxworth E.H.F.				Rothamsted			
Primary cultivation treatment	% Straws with eyespot	% Straws with *Fusarium* foot rot	% Plants with take-all	Yield t ha^{-1}	% Straws with eyespot	% Straws with *Fusarium* foot rot	% Plants with take-all	Yield t ha^{-1}
Plough	70	31	23	6·24	70	17	58	5·66
Shallow plough	78	34	22	5·95	68	20	60	5·34
Chisel plough	68	35	21	6·04	64	22	51	5·31
NIAE rotary digger	67	42	30	5·81	72	29	64	5·32
Rotary digger	71	37	24	6·05	65	23	63	5·42
Direct drill	50	35	16	6·05	64	24	54	5·33

Rhynchosporium secalis *on winter barley*. In an experiment (*Rothamsted Report for 1974*, Part 1, 230) where winter barley (cv. Maris Otter) was grown after different cultivations (ploughed (PL), tine cultivated (TC) and direct drilled (DD)), crop infection and the production of spores by *Rhynchosporium secalis* were measured. Counts at approximately 21-day intervals were made of the spores washed from the plants cut from four random 30-cm row lengths per treatment. Early in the winter there were fewer spores from the PL crops than from TC or DD crops (see Table 11), this was reflected in the infection of the crop in January (percentage of leaf area infected third leaf down) PL 0·8, TC 6·2 and DD 5·6. These differentials gradually lessened and by mid-March the crops were similarly infected (percentage of leaf area infected second leaf down) PL 6·6, TC 6·7 and DD 7·0, and spore numbers had increased to several million per plant on all crops. With few exceptions, spore numbers continued to increase until early July, but the dry summer limited the development of the disease which reached a peak in early June (percentage of leaf area infected second and third leaves down) PL 10·0, 9·0, TC 6·2, 8·0 and DD 3·2 and 11·2 respectively. Very few new infections developed subsequently. The DD crops had fewer plants, which were unevenly distributed and this might have limited

TABLE 11

Rynchosporium *spores (millions) per plant*

	Ploughed	Tine cultivated	Direct drilled
13 December	0	0·05	0·06
2 January	0·01	0·37	0·33
15 January	0·02	0·29	0·07
11 February	0·75	0·64	0·30
28 February	3·85	2·85	0·09
20 March	5·30	4·97	3·76
21 April	7·65	2·72	2·53
7 May	3·05	2·78	1·72
21 May	12·10	6·09	5·49
5 June	14·10	9·22	11·05
26 June	31·50	23·75	40·50
7 July	31·90	15·85	45·25
29 July	10·90	6·55	18·30

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the infection in June, but some plants were much larger than in the other crops which probably accounts for the very large figure of 45 million spores per plant recorded in July. Spore numbers decreased on all treatments in the three weeks preceding harvest on 29 July. (Stedman and Prew)

Effect on paraquat on* R. secalis *on stubble and volunteers. In reduced cultivation systems Gramoxone is extensively used to kill weeds and 'disease-harbouring volunteers'. On a site which had grown Maris Otter winter barley for two years, sprays of 'Gramoxone' (200 g paraquat litre^{-1}) at 330 litres ha^{-1} were applied to the stubble on six occasions at three-week intervals between late August and early December. When possible, weekly samples of stubble and volunteers were washed and spores counted to compare the sporulation of the fungus on sprayed or unsprayed plots. On all plots spore numbers declined by 90% between harvest and mid-September, rain then ended the prolonged dry weather and sporulation increased 18 times within two weeks. Paraquat had no effect on sporulation. Spores were still present on stubble in mid-December, when counts of 600 cm^{-1} length of stubble were recorded (harvest count 3000). Volunteers had not germinated when the first two sprays were applied, but sprays 3, 4, 5 and 6 increased sporulation by 475, 140, 215 and 144% respectively on samples taken seven days after spray application. Sporulation declined as plants died but 6000 spores were washed from each volunteer plant nine weeks after spray 3 was applied. (Stedman)

Diseases of grass and forage crops

Ryegrass mosaic virus (RMV)

Plant infection and dispersal of vector. Results of glasshouse experiments reported last year (*Rothamsted Report for 1974*, Part 1, 231) showed that *Abacarus hystrix*, the eriophyid mite vector of RMV, did not thrive on infected S22 Italian ryegrass plants. In subsequent experiments, mites multiplied similarly on healthy and infected plants until RMV symptoms became evident, when they failed to thrive and dispersed more than from healthy plants. In the field, fewer mites were present on infected than on healthy plants of S22, and the change after infection in the suitability of ryegrass for *A. hystrix* may be important in aiding the spread of the virus in fields.

Infection by RMV decreased the total water-soluble carbohydrate content of leaf tissue, although it increased the amount of reducing sugars (with M. Finney); it is not known whether these changes are the cause of the decreased suitability of infected plants to mites. (Gibson)

Selection of RMV-resistant ryegrass plants. Last year we reported that some old swards of S23 perennial ryegrass had surprisingly few RMV-infected plants, suggesting that there had been a natural selection of the more resistant plants. This year more fields were sampled for RMV incidence. Healthy plants from these fields were grown on in a glasshouse and inoculated with sap containing RMV; preliminary results indicate that plants from older swards are more difficult to infect.

Of 108 healthy plants collected from fields in 1974, two remain undiseased after repeated sap inoculations. Vegetative progenies of these two plants did not become diseased by viruliferous mites or by sap inoculation. Their sap seemed not to contain RMV particles and did not infect susceptible S22 Italian ryegrass. We are now inoculating these plants with potentially different strains of RMV and testing some outside against natural infection (Gibson, with Dr. A. J. Heard, Grassland Research Institute)

Repeated sap-inoculation of 150 seedlings of S22 caused disease in all but one. This survivor, propagated vegetatively and infested with viruliferous mites or inoculated with

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infectious sap, became diseased much less frequently than did seedlings from a commercial stock. (Gibson)

Effect of RMV on yield at different temperatures. To test the hypothesis that the effects of RMV are ameliorated in warm conditions (*Rothamsted Report for 1974*, Part 1, 231), the Italian ryegrass S22 and the perennial S24 were grown in controlled environment cabinets at either 28°C day (16 h), 13°C night or 21°C day, 13°C night. These were the mean summer maxima and minima inside and outside the polyethylene film house.

Dry matter yield of S22 was depressed more (32%) by infection than that of S24 (15%). Losses for S22 were similar at both temperatures when first harvested but greater at 21°C (33%) than at 28°C (23%) when harvested six weeks later. The yield of S24 was also decreased more at 21°C (20%) than 28°C (12%). Tiller number was decreased by 25% in S22 infected with RMV, but increased in S24 by 8%. Decreased effects of virus at higher temperatures may be a drawback to experiments in polyethylene film houses. (Plumb and Gibson)

Symptoms, yield and virus concentration. Italian ryegrass varieties tolerant of infection by RMV may contain a greater concentration of virus particles than those affected most (Chamberlain, *Annals of Applied Biology* (1975), **81**, 264–266). The S22 plants grown in controlled environments (see above) showed a range of symptoms of RMV infection from severe necrosis to slight mottling. To determine whether such large differences in symptoms and differences in temperature were correlated with particle concentration, samples were prepared from 10 of the youngest fully expanded leaves of 11 plants each from the 21° and 28°C cabinets, using the polystyrene latex method of Nixon and Fisher (*British Journal of Applied Physics* (1958), **9**, 68–76). The numbers of latex and virus particles in droplets were counted until at least 100 virus particles had been seen. Virus particle concentration was calculated from the known concentration of latex and expressed as number per unit dry weight. The concentration of RMV was less at 28° than 21°C and although this difference (23%) was not significant, it is consistent with the slightly smaller losses in yield at 28° than 21°C. There was no correlation between individual plant symptoms, yield and virus concentration. (Plumb)

Residues of endosulfan. In an experiment to improve the timing of endosulfan sprays to kill the vector of RMV (*Abacarus hystrix*), plots of Italian (S22) and perennial (S24) ryegrass were treated at monthly intervals. One, two, three and six weeks after the July spray, samples of grass, roots and soil were assayed for endosulfan and its sulphate metabolite. During this period the total residues on grass decreased from 2·74 to 0·66 ppm dry weight, whereas in roots they increased from 0·34 to 0·54 ppm and in the soil they fluctuated about a mean of 0·08 ppm dry weight. The results for grass and roots show less residues than previously measured (*Rothamsted Report for 1974*, Part 1, 233) and the sulphate metabolite was present only in trace amounts. These smaller residues may be due to rapid volatilisation from the foliage during the hot weather.

Plots sprayed monthly from July to October had only seven mites per tiller in November whereas unsprayed plots had 1000 per tiller. However, of plots sprayed once, those sprayed in July had 250 mites per tiller and those sprayed in October 500 per tiller. This suggests that the denser crop later in the year restricted the penetration and effectiveness of the spray. (Austin, Plumb and Gibson, with Manlove, Chemical Liaison Unit)

Hopper-transmitted agents, European wheat striate mosaic, and oat sterile dwarf virus. Fortunately, for both cause a severe and often lethal disease in their hosts, the two hopper-transmitted agents that infect cereals, European wheat striate mosaic (EWSM) and oat

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sterile dwarf virus (OSDV), are rarely prevalent. It is likely that grasses are reservoirs of vectors and agents, so sweepnets were used to sample hoppers from grass and grass–clover mixtures from May to July. Nineteen leafhopper and two planthopper species were caught, but only *Javesella pellucida*, which represented 4·5% of the total catch, caused symptoms when fed on test plants. Only 3·3% carried EWSM and 12·6% OSDV, which although unlikely to cause severe damage to grass swards, may have a generally debilitating effect over several years. (Plumb, with Mr. J. A. O. Medaiyedu)

***Sclerotinia* rot of red and white clover.** English broad red clover and S100 white clover were planted in boxes containing soil taken from the Rothamsted Garden Clover experiment which has grown only red clover for over 100 years. As in previous years little rotting of red clover was observed before January or February but most plants which showed symptoms were eventually killed. By contrast, rotting of white clover foliage, which was first observed in October, had become severe by mid-November and in early December newly produced sclerotia were observed on the soil surface. However, few stolons became diseased and most white clover plants survived. Similar symptoms were observed in field plots of white clover in October and November 1975. (Jenkyn and Macfarlane)

Crown wart of lucerne (*Urophlyctis alfalfae*). The occurrence of this disease at Saxmundham, reported last year (*Rothamsted Report for 1974*, Part 1, 232) provided opportunity for observations on the causal fungus. Most species of *Urophlyctis* and the closely related *Physoderma*, biotrophic parasites of higher plants, possess two separate and independent stages in their life cycles. The first is epibiotic, a single zoosporangium outside the host plant into which it sends rhizoids; the second, endobiotic stage, is a branching mycelium that spreads within the host tissues and bears resting sporangia. The endobiotic thallus of *U. alfalfae* begins developing in the crown buds early in the year, causing them to form the crown warts. Epibiotic sporangia of *U. alfalfae* have not been previously reported but, if they occurred, would probably be found on the bud scales during winter, following infection by zoospores from germinating resting sporangia. To investigate this possibility, crowns of diseased lucerne plants were brought from Saxmundham during January and February and on many bud scales epibiotic zoosporangia of the *Urophlyctis–Physoderma* type were found, sometimes numerous, on both surfaces of the scale leaves, and occasionally deep inside the bud. Chytrid zoospores were seen but details of development have not yet been observed. Some bud scales had epibiotic sporangia attached to surface cells and young endobiotic *U. alfalfae* within the tissues. It is most likely that these epibiotic sporangia are a stage of *U. alfalfae*, although this requires confirmation. (Macfarlane)

Health of forage maize at ARS Institutes in south-east England

The survey. In April 1975 maize workers within the ARS expressed a wish to have their crops examined for pests and diseases. Subsequently, crops at the Grassland Research Institute (GRI), Institute for Research on Animal Diseases (IRAD), National Institute for Research in Dairying (NIRD), Plant Breeding Institute (PBI) and Rothamsted (totalling *c.* 120 ha in 13 different fields) were examined at intervals between July and October 1975. Although the hot, dry summer favoured some diseases, no pest or disease (with possible isolated exceptions of *Fusarium* stalk rot) seemed to seriously decrease yield. Minor leaf and sheath disorders (bronzing, chlorosis, stripes, blotches, spots, puckering etc.) were common, but few could with certainty be attributed to specific causes. The most conspicuous problems in July were weeds and patches of poor growth on unsuitable sites.

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Fungi. *Fusarium culmorum* was isolated from roots at Woburn as early as June; by the beginning of September it was generally evident on damaged plants and aborted ears and by the beginning of October it had caused much stalk rot at the NIRD (Table 12). Common smut was first noticed at the end of August, but although it was widespread, it never became as intense as *Fusarium* stalk rot (Table 12). *Alternaria* sp., *Cladosporium* sp., *Epicoccum purpurascens* and *Stemphylium* sp. were isolated frequently from leaf spots, lesions or flecks and *Acremonium zeae* was associated with purple sheath blotches.

Nematodes. On most sites numbers of *Pratylenchus* spp. were low and comprised species thought not to cause damage (*P. neglectus* and *P. crenatus*). However, the large infestation on one site at the GRI may have been damaging. On two sites at the NIRD the potentially damaging species *P. fallax* was present in moderate to large numbers in stunted plants (Table 12). Weeds in these areas contained high numbers of *Pratylenchus* spp. Well growing maize from these sites contained fewer nematodes. Cereal cyst nematode and stem nematode were not found.

TABLE 12

Incidence of fungus and nematode pathogens in some maize crops in south-east England

Institute	Field	No. of consecutive maize crops	Date 1975	% Plants with		*Pratylenchus* spp.	
				Common smut	*Fusarium* stalk rot	No. g^{-1} root	% *P. fallax* in population
GRI	Chapelfield I	3	2 October	6·0	0	1056	0
	Vetchingtons IV	1	2 October	2·0	0	19	0
NIRD	Warren North						
	(west end)	1	1 September	13·6	0	320	39
	(east end)	1	2 October	3·5	25·0	—	—
	Wyverley Home	4	1 September	3·3	0	1792	48
			2 October	2·0	33·0	—	—
PBI	Cottage Field	1	1 October	Trace	Trace	—	—
Rothamsted	Butt Furlong	4	28 August	Trace	—	342	0
	(Woburn)		22 October	0·1	1·4	—	—

Insect pests. In July less than 5% of plants had symptoms of frit fly attack (see Bardner, Entomology Department, p. 125) and even fewer had been attacked by leaf-feeding Lepidopterous larvae.

Viruses. Only barley yellow dwarf virus was found and few plants were infected. There was no consistent association of infection with symptoms, although bronzed, chlorotic, striped and spotted plants were examined. Its only vector found in the survey was *Macrosiphum* (*Sitobion*) *avenae*, which was common in early July at Rothamsted. (Hornby and Plumb, with Bardner, Entomology Department, Barnard, Field Experiments Section and Webb, Nematology Department)

Diseases of field beans (*Vicia faba* L.)

Virus survey, 1975. We again helped with a survey of viruses in spring-sown field beans organised by the Agricultural Development and Advisory Service (*Rothamsted Report for 1974*, Part 1, 235). Eight crops, including four grown from basic or pre-basic seed, were examined in Essex and Hertfordshire. Seed-borne infection with the seed and weevil-borne viruses, broad bean stain (BBSV) and Echtes Ackerbohnenmosaik (EAMV),

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was detected in five of the crops at the first inspection in late May to mid-June, the incidence ranging from 0·02 to 1%. At the second inspection towards or at the end of flowering in July, BBSV and/or EAMV were detected in all eight crops, incidence ranging from 3 to 60% in crops with seed-borne infection and 0·4–2·3% in crops that initially seemed virus-free. The incidence of bean leaf roll virus (BLRV) in July ranged from 0·3 to 24%, bean yellow (pea) mosaic virus (BYMV) 0·4–30% and pea enation mosaic virus (PEMV) 0·2–22%. (Cockbain and Bowen)

TABLE 13

Effects of insecticides on the incidence of weevil-borne viruses and yield of field beans

	% Plants with symptoms of BBSV/EAMV			
	24 June	10 July	25 July	t ha^{-1}
nil	6	30	37	1·41
phorate (P)*	5	19	32	1·44
malathion (M)**	4	12	17	1·74
fenitrothion (F)**	3	12	14	1·91
P + M	5	14	16	1·92
P + F	2	8	10	1·93
SE of differences				±0·118

* Granules applied 22 May and 20 June
** Spray applied 22 May and 18 June

Effects of insecticides on virus spread and yield. As in 1974 sprays of fenitrothion (applied twice at 0·74 kg a.i. ha^{-1}) or malathion (2 × 1·0 kg) were more effective than phorate granules (2 × 1·0 kg) in checking the spread of BBSV and EAMV in plots of cv. Maris Bead grown from an infected seed stock (*c.* 1% of seeds were infected with BBSV and 0·7% with EAMV) (Table 13). Adult weevils were common on all plots four weeks after the first application of insecticides (*c.* 12 *Apion vorax* and 19 *Sitona lineatus* on the foliage per 10-m row), but five days after the second application there were 71% fewer *A. vorax* on plots treated with phorate granules than on untreated plots, 75% fewer on those sprayed with fenitrothion or malathion and 95% fewer on those treated with both granules and spray. For *S. lineatus* there were respectively 47, 95 and 98% fewer than on untreated plots. Aphid-borne viruses were uncommon; in late July *c.* 2% of plants in untreated plots were infected with PEMV, 3% with BYMV and 4% with BLRV (all plots were sprayed with menazon in early July to prevent aphids damaging 'untreated' plots). All treatments except phorate significantly increased yield, malathion by 23% ($P = 0·05$) and fenitrothion by 35% ($P = 0·001$), but all yields were very poor because of drought. Seeds from this experiment are still to be tested for virus infection. (Cockbain and Bowen, with Etheridge, Insecticides and Fungicides Department)

In another experiment (75/R/BE/7) aldicarb applied along the rows at drilling decreased weevil populations and checked the spread of BBSV and EAMV in plots sown with seed from the same stock as that used in the previous experiment. In late July the incidence of BBSV/EAMV in plots with 0, 1, 2 and 4 kg a.i. ha^{-1} was, respectively, 40, 29, 19 and 15% (see also Hooper, Nematology Department, p. 203).

Effects of BBSV and EAMV on yield. In field plots, plants of cv. Maris Bead infected through the seed with BBSV or EAMV yielded, on average, 69% fewer pods and 76% less weight of seed than did plants that were without symptoms at the end of flowering. Plants that were initially virus-free but which developed symptoms before or during flowering yielded, respectively, 42 and 14% fewer pods and 52 and 24% less seed than plants without symptoms.

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Biology and ecology of *A. vorax*. Observations at Rothamsted in winter and early spring showed that adults of *A. vorax*, the main vector of BBSV and EAMV, were much more common in woods alongside fields cropped with field beans in 1974 than in hedgerows bordering similar fields, but were rare in woods 250–500 m away. These results suggest that migration from bean crops in late summer is very local, at least when there are suitable overwintering sites nearby. In winter most *A. vorax* were found on *Galeobdolon luteum* (yellow archangel) and *Rubus* spp. (bramble), and a few on old shoots of *Mercurialis perennis* (dog's mercury) and in tussocks of grass; in early spring most were found on *M. perennis*, *Rubus* spp., *Sambucus nigra* (elder) and *Urtica dioica* (nettle).

Approximately 300 adult *A. vorax* (40% females) were caught between April and November on four sticky traps 1·5 m above ground level in a copse at Rothamsted bordering fields cropped with field beans in 1974. The largest weekly catch (53 females and 65 males) was in late April, this coinciding with the time that adults were first detected on autumn-sown beans (because of late sowing most spring beans did not emerge until the second week in May).

EAMV was detected in *Vicia sativa* (common vetch) at Rothamsted in April, and adult *A. vorax* were found on this species in May. The possibility that EAMV (and BBSV) can overwinter in seeds or plants of *V. sativa* is being investigated. (Cockbain and Bowen)

Chocolate spot and yield of winter beans. A factorial experiment originally designed to examine interactions between seed rate, row spacing and fungicide treatment against chocolate spot (*Botrytis fabae*) had little disease and consequently the only significant differences in yield were due to differences in plant population. Best yields (4·37 t ha^{-1}) were obtained from closer row spacing (18 v 53 cm) combined with heavier seed rate (126 v 377 kg ha^{-1}). This was 24·5% better than the yield obtained from wide rows and low seed rate. (Bainbridge)

Diseases of grain lupins

Two species of grain lupin, *Lupinus albus* L. (Kievsky mutant) and *L. angustifolius* L. (Unicrop), were grown at Rothamsted in 1974 to assess effects of different factors, including pests and diseases, on growth and yield (see Field Experiments Section Report, p. 147, and Soil Microbiology Department Report, p. 284).

Virus diseases. Two aphid-borne viruses, bean yellow mosaic (BYMV) and one resembling clover yellow vein (CYVV), were isolated from diseased plants of both species. Younger leaves of *L. albus* plants infected with BYMV were small and erect, often malformed, and showed a green or green and yellow mosaic. In *L. angustifolius* plants infected with BYMV, the shoot tip curled downward and the leaves drooped; this was followed by stem discoloration and early leaf abscission. CYVV caused leaf yellowing and stem necrosis in both species and the younger leaflets often showed necrotic spots or patches. About 1% of plants were showing symptoms when the lupins came into flower; they were stunted, produced few or no pods and died prematurely. Later in the season virus-infected plants, particularly those infected with CYVV, were difficult to distinguish from plants with wilt symptoms caused possibly by *Fusarium* spp. (Cockbain, Bowen and Govier)

Fungus diseases. Wilted plants of both *L. albus* and *L. angustifolius* were observed in July. Vascular staining was often associated with the symptoms and *Fusarium* spp. were commonly isolated from the stems and roots. Late in the season, powdery mildew became severe on *L. angustifolius*. (Jenkyn and Salt)

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Insect pests. Five species of aphid were recorded on the lupins: *Aphis fabae* Scop. *Aulacorthum solani* (Kltb.), *Brachycaudus helichrysi* (Kltb.), *Macrosiphum euphorbiae* (Thos.) and *Myzus persicae* (Sulz.). *B. helichrysi* was the only species found in mid-June (on 35% of *L. albus* plants and 16% of *L. angustifolius* plants), but the nymphs produced by immigrant alatae rarely seemed to survive for more than a few days, particularly on *L. angustifolius*. *M. euphorbiae* appeared in late June and *A. fabae* towards mid-July. Colonies of these species built up more than did those of *B. helichrysi*, but few plants were infested by more than about 50 aphids and direct damage seemed to be slight. *A. solani* and *M. persicae* were found only occasionally, and mainly on *L. albus*.

Adult weevils (*Sitona* spp.) were very common early in the season. They caused much more damage to *L. angustifolius* than to *L. albus*, particularly in plots that were not treated with aldicarb. (Cockbain, Bowen and Barbagallo)

Diseases of *Brassica* crops

Oilseed rape (*Brassica napus* spp. *oleifera*)

Incidence of diseases in 1975. The area sown to this crop continues to increase greatly and in Britain is now approaching 40 000 ha. Before 1975 most crops were free from severe attacks by fungi and viruses, but this year many were infected by *Pyrenopeziza brassicae*, imperfect stage *Gloeosporium* (*Cylindrosporium*) *concentricum*, a fungus not previously recorded from rape on which it causes leaf spot and scorch symptoms. Commonly a disease of vegetable brassicas, and usually confined to the south-west, it was widespread on winter oilseed rape (WOSR), and on some cultivars it killed many seedlings during the winter. The leaves and later the inflorescence of surviving plants were often severely attacked and withered. First noticed in February, the incidence of this and other foliar diseases was recorded on 50-plant samples taken in May from 19 sites, totalling over 300 ha of cv. Rapol, Primor, Victor, Lesira and Eurora, mainly in Hertfordshire and Bedfordshire.

Pyrenopeziza brassicae was recorded on 41% of all plants examined, the symptoms being most severe on cv. Eurora, Lesira and Rapol. The most frequently recorded disease was downy mildew (*Peronospora parasitica*) on 57% of the plants. Symptoms were most severe on the lower leaves of cv. Victor and Rapol. Although the incidence of *Botrytis cinerea* was low (4%), infection at a lower leaf scar usually caused wilting and death of whole plants, and lesions on the inflorescence caused wilting and death of distal parts of the inflorescence. An aphid-transmitted yellowing virus disease causing symptoms similar to those of viruses of the beet western yellows virus (BWYV) group was detected in a few plants from each of six crops (cv. Lesira, Rapol and Victor), but appeared to have little effect on plant growth. (Rawlinson and Muthyalu)

Effect of herbicide on leaf disease. The herbicide dalapon is widely used on WOSR crops to control volunteer cereals and grass weeds, and usually retards growth and flowering of rape only slightly. However, during the prolonged wet winter of 1974–75, dalapon was associated with increases in severity of disease caused by *Pyrenopeziza*. This effect was also seen in Bedfordshire within adjacent direct drilled crops of cv. Rapol and Victor (both sown in August and treated with 3·3 kg ha^{-1} dalapon in late September). The incidence and severity of disease in dalapon-sprayed and unsprayed areas were compared in May and components of yield measured in July.

Symptoms of *Pyrenopeziza* infection were slight in cv. Victor (two to three infected leaves per plant on 44% of unsprayed and 52% of sprayed plants), but severe in cv. Rapol (four to six leaves infected on all plants examined). Symptoms were especially severe on the dalapon-sprayed area of cv. Rapol where plants had died; the percentages of those

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surviving with slight, moderate or severe symptoms were 32, 48 and 20% respectively, compared with 68, 28 and 4% for unsprayed plants. Analysis of pods and stems by gas chromatography showed no residues of dalapon in May. No differences were apparent with *Peronospora parasitica* which infected the lower leaves of all cv. Victor plants and 80% of cv. Rapol.

In July there were three times as many plants m^{-2} in the dalapon sprayed area than in the unsprayed area of cv. Victor, contrasting with 34% fewer plants m^{-2} in the sprayed area of cv. Rapol, and sprayed plants of both cultivars were shorter than those not sprayed. Sprayed plants of cv. Victor, being more numerous, had fewer branches and pods per plant with fewer seeds per pod which resulted in greatly decreased (64%) yields per plant and per unit area (36%) compared with unsprayed plants. In contrast sprayed plants of cv. Rapol had more branches and pods per plants and more seeds per pod than unsprayed plants, but because there were fewer plants, yield per unit area of crop was decreased by 18%.

The differences in plant population following dalapon treatment in the two cultivars may be explained by the relatively greater susceptibility of cv. Rapol to infection by *Pyrenopeziza* and the fact that the weed problem from volunteer barley was not so marked as in the crop of Victor. Dalapon, by controlling a severe weed problem in cv. Victor increased the plant population without loss from disease, whereas in cv. Rapol the treatment was associated with increased susceptibility and death of plants with less benefit from weed control.

Observations on other areas within these crops, and on a nearby crop of cv. Lesira, indicated that *Pyrenopeziza* infection was more severe on areas given late sprays of dalapon (October–December) than on those sprayed in September. (Rawlinson, Muthyalu and Austin)

Effect of herbicides on leaf surface wax. The apparent connection between the use of dalapon and increased severity of attack by the splash-dispersed subcuticular pathogen *Pyrenopeziza* led us to examine the effect of applying recommended rates of dalapon and carbetamide on the development of cuticular wax on seven WOSR cultivars. Plants grown under controlled conditions at day/night temperatures of 15/10°C were sprayed once at the four-leaf stage with the product equivalent of either 4·5 or 3·1 kg ha^{-1} dalapon or carbetamide respectively. Changes in wax structure and distribution on leaves 4–7 were recorded on scanning electron micrographs for up to one month after spraying, and the proportions of leaf surface occupied by wax structures were measured on photographs using a Quantimet 720 image analysing computer. Changes in wettability of leaves were measured from the contact angles made on leaves by 0·5 μl water droplets applied with a micro-applicator.

Both products decreased the amount of wax on leaves and thereby increased their wettability, but these effects were much greater following dalapon. Leaves contacted by dalapon spray had up to 68% less wax cover than unsprayed leaves. Later developing leaves, affected only by translocation, had up to 52% less wax. The build up of a wax cover on leaves formed later was also slower after dalapon than carbetamide. These effects may explain why plants in the field treated with dalapon were more severely attacked by *Pyrenopeziza* than unsprayed plants.

Although most of the low erucic acid (LEA) cultivars of WOSR had less wax and consequently more wettable leaves than the high erucic acid cultivars tested, the differences were not sufficiently consistent to explain the apparent greater severity of *Pyrenopeziza* on LEA cultivars in the field. However, within the LEA group of cultivars a comparison between cv. Primor (relatively resistant to *Pyrenopeziza*) and Eurora (relatively susceptible) showed that Eurora had less wax and more wettable leaves. Treatment with

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dalapon increased leaf wettability in both cultivars by up to 53%. (Rawlinson, Turner and Muthyalu)

Effect of reduced cultivation on leaf diseases. There was no difference in the incidence or severity of *Pyrenopeziza* on WOSR cv. Lesira grown on plots that had been either ploughed, tine cultivated or direct drilled in long-term tillage experiments at the Letcombe Laboratory's Northfield and Englefield sites near Wantage.

In February on the Northfield site *Pyrenopeziza* was isolated from leaves which had symptoms similar to the scorch caused by nitrogen application or frost damage, but by May most leaves and stems had distinct lesions and the incidence of infection was 100% in all plots. *Peronospora parasitica* and *Mycosphaerella brassicicola* were also present, but not in sufficient amounts to assess the effects of cultivation. (Prew and Rawlinson)

Aphid-transmitted yellowing virus disease. Symptoms similar to those caused by viruses of the beet western yellows virus (BWYV) group were noted in winter crops of oilseed rape, sprouts and kale. In glasshouse tests *Myzus persicae* fed on affected leaves for at least 48 h transmitted 28 nm virus particles to, and caused typical BWYV symptoms in, *Claytonia perfoliata*, *Senecio vulgaris* and *Capsella bursa-pastoris*, but not sugar beet or radish. In host range tests the virus was also transmitted to *Erysimum suffruticosum*, *Nicandra physaloides*, *Dianthus armeria*, *Brassica napus* cv. Rapol, Mogul and Sinus and *B. oleracea* cv. Maris Kestrel and Gigantea. (Rawlinson and Muthyalu)

Powdery mildew and virus diseases of swedes. Swedes sown early (1 May) or late (23 June) were either untreated, sprayed with benomyl or tridemorph to control mildew, or sprayed with tridemorph and pirimicarb to control mildew and aphid vectors of viruses. On early-sown swedes, mildew was first seen in late July and, in untreated plots which yielded 20·6 t trimmed roots ha^{-1}, had become severe by mid-August (*c.* 75% leaf area affected). The disease was much decreased by fungicides, especially tridemorph (*c.* 5% leaf area affected) which increased yield to 28·4 t ha^{-1}. The first symptoms of virus infection were seen in late August, following severe infestations with the aphids *Myzus persicae* and *Brevicoryne brassicae*. By late September many plants in early-sown plots were severely stunted by a combination of at least three viruses, viz. turnip mosaic, cauliflower mosaic and turnip crinkle. Pirimicarb decreased aphid numbers but apparently had no effect on virus incidence, although plots sprayed with tridemorph and pirimicarb yielded most (35·4 t ha^{-1}).

Late-sown plots emerged patchily with 20% fewer plants than early-sown plots. Mildew was severe in untreated plots by mid-September (*c.* 70% leaf area affected) and yielded 19·8 t ha^{-1}, similar to untreated plots sown early. In November all late sown-plots were much less affected by viruses than early-sown (29 and 66% plants affected respectively). Late-sown plots sprayed with tridemorph, or tridemorph and pirimicarb, yielded respectively 20·8 and 21·3 t ha^{-1}, which was not significantly different from untreated plots. By contrast benomyl sprays increased yields of both early and late-sown crops to 32·4 and 27·5 t ha^{-1} respectively. (Jenkyn and Rawlinson)

Clubroot (*Plasmodiophora brassicae*). Increasing interest in brassica crops was reflected in our resumption of research on clubroot. Effects of some growth regulators and systemic fungicides that might be translocated downwards were investigated in glasshouse experiments. Cabbage, for which suitable inoculum was available, was used as host plant. Seedlings were transplanted singly to pots containing a sand–peat mixture ('EFF' compost) to which a suspension of *P. brassicae* spores, extracted from clubbed

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roots, was added two weeks later, and this infested compost was watered frequently with tap water. When the fresh weights of tops and of clubbed roots were measured five to nine weeks later, 17 compounds (see Report, Insecticides and Fungicides Department, p. 170) had no obvious effect in controlling clubroot, but 0·5% DL-ethionine sprayed two to three weeks after transplanting to infested soil, seemed worthy of further study since it almost doubled the fresh weight of tops but with little effect on weight of clubs; β-hydroxyethylhydrazine had a similar, though smaller, effect. (Macfarlane, with McIntosh, Insecticides and Fungicides Department)

Potato diseases

The season was exceptionally difficult for the potato crop. The winter was wet and soils slow to dry which delayed planting, and despite the planting of high quality strong-sprouted seed (produced in the new temperature controlled stores) emergence in parts of two experiments was patchy because of rotting in cold wet soil. After planting, apart from 37 mm rain in mid-May, there was no rain until mid-September and consequently growth and yield of unirrigated crops suffered badly. Soil temperatures at tuberising depth from June to early September often exceeded 20°C, and during August 25°C, for many hours per day.

Bacterial soft rots

Activity in soil. We have continued to assess the survival of *Erwinia carotovora* var. *atroseptica* and var. *carotovora* in field soils by fortnightly samples of soil artificially infested with either of the two bacteria. Each month a set of open-ended tubes, 15 cm long were filled with infested soil, sunk vertically to soil level and sampled for a period of 20 weeks. In experiments started between December and April, the bacteria were still detectable after 20 weeks but in those started between May and August they were undetectable after respectively 14, 12, 8 and 6 weeks. The survival of the two varieties was similar but initially populations of var. *carotovora* appeared to remain higher for longer during the warm summer months.

Lifting of the Rothamsted potato crop in 1974 was delayed and made difficult by rain. Soil taken periodically from areas of fields known to have had soft-rotting tubers and which had been flooded, showed that under these conditions *Erwinia* spp. readily survived into late April when sampling stopped. (Legg and Lapwood)

Effect on growth and yield. Sprouted seed of the cultivars King Edward, Majestic and Pentland Crown were stab-inoculated with var. *atroseptica*, either at the stolon scar, in the middle or at the apical end, or not, just prior to planting in replicated plots. The effect of disease on above-ground growth was assessed from individual plant descriptions *in situ*, in June and July and on yield from harvest in early October. Apical inoculations had the greatest effect, decreasing plant stand, average height, stem numbers and yield. Heel end inoculations had the least, although even these inoculations showed a significant effect of disease (Table 14). Majestic was the cultivar most severely affected in growth and King Edward in yield whereas Pentland Crown was least in either respect. (Lapwood, Legg and Harris)

Potato groundkeepers. There is increasing concern about the numbers of groundkeepers surviving the potato crop and their role in perennating fungal and bacterial pathogens. As a prelude to field experiments on their persistence and of the diseases they carry, a survey was done to estimate their numbers at the different stages of the Rothamsted seven-course (one potato crop) and Woburn six-course (sometimes two potato crops, one

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TABLE 14

Total yield of tubers (t ha^{-1}) from different cultivars and inoculation treatments

	Stab-inoculation with *Erwinia*			
	None	Apex	Middle,	Stolon
King Edward	20·3	4·5	7·6	13·3
Majestic	19·3	7·0	7·9	15·0
Pentland Crown	30·6	11·9	12·7	18·9
SED ±	1·99			

being eelworm resistant) rotations. The timing of the survey was determined by the current field crop. Beans were surveyed in June, and cereals after combining in September. The most persistent groundkeepers in rotational fields were from the 1970 potato crop at Woburn and the 1971 at Rothamsted. Counts were always greater in June than September and greater in beans than in winter cereals, but whether this was due to the crop or time of assessment is not clear. At Rothamsted the greatest numbers were found in beans after the 1973 potato crop (34 000 ha^{-1}) and fewest in cereal stubble after the 1974 crop (180 ha^{-1}). (Hide, Lapwood and Bell)

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

Detection of the pathogen in soil. Slices of Arran Banner tubers were used routinely to assess soil populations, and were calibrated by inoculation with soils infested with known populations of pycnospores. Populations as low as 10^2 spores g^{-1} soil could be detected and half the slice wounds developed rots after inoculation with soil containing $2{\cdot}5 \times 10^4$ spores g^{-1}. However, test slices would be expected to differ in susceptibility as the tubers age.

Various recipes and methods have been tested in the search for a suitable selective agar medium for isolation from soil. Isolation on a satisfactory medium has proved very sensitive to the method of plate inoculation, the amount of moisture on the agar surface and the incubation temperature. However, with care such a method gives a more direct assessment of population than the slice test, can be a uniform substrate throughout the year, and yields results in one rather than eight weeks. Preliminary results suggest that it may not be as sensitive as the slice test to small populations of the pathogen. (Adams)

Spread and survival. In a field experiment at Rothamsted in 1974, seed tubers inoculated with the E positive strain of var. *foveata* were separated in the rows by three healthy tubers. At intervals during the growing season, soil samples were taken at various distances along the ridge away from the inoculated seed tuber, and at the end of the season the presence of the pathogen in all soils was tested by the Arran Banner tuber slice technique. Subcultures were made from all rots which developed after eight weeks storage at 5°C and the strain of the pathogen identified. The E + ve strain moved very little through soil, but was occasionally isolated up to 20 cm from the seed tuber. When wounded and stored at 5°C for 12 weeks, progeny of adjacent plants occasionally developed rots of the E + ve strain, but spread over greater distances was not detected. In this and other experiments in which soil and progeny tubers were periodically sampled during the season, the inoculum fluctuations were not simply related to meteorological conditions. However, in the very dry summer of 1975, var. *foveata* was not detected in soils around infected seed tubers between May and September.

The survival of var. *foveata* under various conditions has been studied using soils inoculated with pycnospores to give an initial population of about 10^6 spores g^{-1} soil. In soils sterilised before inoculation populations detected by isolation on to a semi-selective

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agar medium remained constant or even increased over a period of 24 weeks, but in non-sterile soil, populations declined and at 15°C were no longer detectable after 20–24 weeks. At lower temperatures populations declined slightly less rapidly. Results of slice tests in 1974 suggested that natural soil populations also declined if the soil was stored for long periods (e.g. six months at 2–5°C). Although pycnospores are small, hyaline and thin walled, they can survive in soil for several months and there is some evidence that natural populations may be at least partly in this form. (Adams)

Screening of compounds for fungitoxicity. In a search for fungicides effective against var. *foveata*, 15 benzimidazole and related compounds were screened by placing drops of solutions containing 3 and 0·3 μg in small wells cut out of malt agar plates which had been centrally inoculated with the fungus. All the compounds were ineffective on agar of pH 5·4, but at pH 7·0, thiabendazole, benomyl, fuberidazole and carbendazim inhibited fungal growth. At pH 8·5 their effect was enhanced but the other compounds, including the commercial fungicide thiophanate methyl, remained ineffective. (Adams and Austin)

Potato and red beet scab (*Streptomyces* sp.). Scab on red beet is caused by a similar (or perhaps identical) organism to the potato pathogen, but the relationship between pathogen and host is different and if an effective control procedure is to be devised, the time and route of infection must be established. In pot experiments, severe scab symptoms were produced on cv. New Globe by placing mycelium from a liquid culture around the growing hypocotyl for a week, washing it off and transplanting to clean soil. Little scab developed from inoculation of plants less than 40 days old, whereas much scab appeared on plants inoculated 46 days after planting, when about six leaves had expanded and decortication had begun. Other inoculation and transplanting experiments together with anatomical studies of the depth of lesion penetration also indicated that developing beet become particularly susceptible at and just after decortication. Decortication usually occurred at the 6–8 leaf stage when 3–4 vascular rings were present in the hypocotyl, and this exposed the pericycle which became suberised over a two-week period. It seems likely that this unprotected surface is at least one of the routes by which the pathogen penetrates. Although scab has occasionally been reported on radishes, similar inoculations of these were unsuccessful suggesting that this disease must be caused by a different pathogen. (Adams and Lapwood)

In a field trial at Woburn, on land severely infested with the potato scab pathogen, beetroot developed rather little scab. The chemicals daminozide and ethionine were applied to plots as a foliar spray on one or a combination of three dates. Ethionine decreased infection to about half that on control plots, but daminozide was only slightly effective. The results of application on different dates were inconclusive. (Lapwood and Adams, with McIntosh, Insecticide and Fungicide Department)

In a further experiment to study the way in which irrigation hinders the development of potato common scab, parts of tuber surfaces from a susceptible cultivar growing in infested soil were examined using the scanning electron microscope. Few micro-organisms were seen on the second internode from the apex, but on older internodes, pieces from wet soil carried many bacteria, while those from dry soil had massive actino-mycete populations. These large differences were rarely detected by isolation on to water agar. (Adams and Lapwood)

Agronomic effects of healthier seed

Effects of fungicides on diseases and yield. It is now accepted that fungicides are

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necessary to maintain the health of seed during multiplication from stem cuttings. At present the fungicides most often used are the benzimidazoles (benomyl, thiabendazole) or 2-aminobutane, but their effects on health of the crop have been less studied than their effects on the treated seed. In 1974 and 1975, healthier and commercial stocks of five cultivars were compared in experiments at Rothamsted and Woburn either untreated, fumigated with 2-aminobutane or dusted with benomyl or thiabendazole. Healthier seed yielded 8% more than commercial at Rothamsted in 1974 but not at Woburn. Fungicide treatment did not affect yields, but at lifting progeny tubers from seed treated with benomyl or thiabendazole had much less *Oospora*, *Helminthosporium* and *Rhizoctonia* than untreated seed. 2-Aminobutane decreased *Rhizoctonia*, but no treatment greatly decreased *Phoma*.

In 1975 yields were restricted by drought and were unaffected by seed health or fungicides at both Rothamsted and Woburn. (Hide, Adams and Bell)

TABLE 15

The effects of fungicides on percentage of tubers infected by various pathogens at lifting, Rothamsted, 1974

	Oospora	*Helminthosporium*	*Rhizoctonia*	*Phoma*
Healthier seed				
untreated	10	47	37	25
benomyl	2	8	18	19
thiabendazole	4	10	10	22
2-aminobutane	10	50	21	22
Commercial seed				
untreated	11	32	52	17
benomyl	1	1	13	27
thiabendazole	2	7	7	23
2-aminobutane	10	49	39	22

Comparison of yields and diseases in crops grown from healthier and commercial seed. In continuing experiments to assess the effects of improved health of seed, samples from 20 commercial King Edward stocks were compared with VTSC (virus tested stem cuttings) and a stock grown at Rothamsted from VTSC.

TABLE 16

The effects of seed source on yield and disease after storage

	Healthier	VTSC	FS 2	Other certified	Once grown
Number of stocks	1	1	2	10	8
Total yield (t ha^{-1})	56·2	60·3	59·9	56·4	55·3
Ware yield (t ha^{-1} > 4·4 cm)	44·8	51·2	48·8	47·8	46·1
Skin spot (% tubers)	19	35	53	51	46
Gangrene (% tubers)	5	15	10	14	11
Silver scurf (% tubers)	16	32	51	50	44
Black scurf (% tubers)	44	8	44	19	21

In 1974, healthier, VTSC and two FS2 stocks averaged 6% more total tubers than the other 18 stocks and 3% more ware. Plot samples were stored at Sutton Bridge Experimental Station, and in May tubers from healthier seed had much less skin spot, gangrene and silver scurf than commercial stocks. Prevalence of these diseases was related to the amount on seed tubers. Although in previous experiments healthier seed yielded more than commercial seed, these results confirm previous indications that the advantage of using healthier seed can be considerably more after storage than the 6–10% increase in yield recorded at lifting.

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In 1975, yields were small and six healthier stocks (including commercial FS1 and 3 stocks) yielded 14% more total tubers than 16 commercial stocks, but ware yields were the same. After half the plots were irrigated, however, healthier seed yielded 18% more total tubers than commercial and 22% more ware. This confirms earlier results (*Rothamsted Report for 1973*, Part 1, 146) that irrigation can increase the yield of crops from healthier seed more than from commercial seed. (Hide and Bell)

The activity of fungicides against tuber pathogens

Thiabendazole uptake and distribution in tubers. Potato tubers cv. Pentland Crown were lifted immature in early July and late August, and in late October when fully mature. At each lifting, sample tubers were dipped in 'Tecto' suspension (a.i., 50 ppm) at pH 3 and kept at 5°C before analysis. Assays of the peel and of core samples showed that no significant differences in uptake existed between immature and mature tubers and that in all samples, essentially all the thiabendazole taken up was confined to the peel, confirming previous results (Tisdale, Lord and Hide, *Rothamsted Report for 1972*, Part 1, 150). (Austin, Rolfe and Adams)

The uptake and movement of thiabendazole in cuttings and tubers. Thiabendazole has now been cleared for use on ware tubers. As part of a programme to improve the health of seed tubers, the uptake and distribution of the chemical have been studied after application by various methods to cuttings and growing plants in compost. Thus, cuttings have been allowed to take up thiabendazole (as the 'Tecto' formulation) from aqueous suspension and from the dust itself. The time-course of uptake was followed by chemical analysis. Uptake from dust was much slower and, in both methods, the more soluble acetate and hydrochloride salts proved to be phytotoxic at all concentrations used.

In pot experiments, cuttings planted in compost containing thiabendazole took up the chemical throughout the growing season and it was found predominantly in the roots, but also in stems and leaves. This distribution occurred after treatment of the rooting medium, treatment of cuttings with 'Tecto' dust and aqueous suspension, and drenching. After foliar spraying, most thiabendazole was found in the leaves but it was also present in stems and roots, presumably after run-off from the foliage. A striking effect of all these treatments was the reduced incidence of *Phoma* pycnidia on stems compared with untreated plants.

Analyses for thiabendazole content of sprayed and 'smoked' tubers have been carried out for the Potato Marketing Board and commercial producers. They will be correlated with disease assessments (particularly for *Phoma*) after storage. (Austin, Davies, Rolfe and Hide)

Potato pests and diseases 1974–75

Pests. Both the potato aphid *Macrosiphum euphorbiae* and the peach–potato aphid *Myzus persicae* were common on potato crops at Rothamsted. In one field experiment spraying with the organophosphorus insecticide 'Metasystox 55' controlled only *M. euphorbiae*, many apterous as well as alate *M. persicae* being found breeding on treated plants sampled only a week after spraying. In laboratory tests, *M. persicae* from this field were found to have greater than usual carboxylesterase activity and elevated LD50 values for the insecticide. (Gibson, with Needham and Devonshire, Insecticides and Fungicides Department.) The development of tolerance to insecticide may become a serious problem in controlling these pests and the virus diseases they transmit. An alternative biological method of controlling aphids and virus spread may be provided from our work on insect-trapping hairs, found originally on the foliage of three wild potato species

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but now also on that of hybrids with the cultivated potato (*Rothamsted Annual Report for 1973*, Part 1, 147). (Gibson)

Potato virus diseases at Rothamsted. When counts were made at the beginning of July, experiments planted with King Edward seed grown at Rothamsted in 1974 contained 0·8% potato virus Y and 0·5% potato leaf roll virus. The resistant variety Pentland Crown had no virus Y and only a trace of leaf roll infection. Numbers of aphids (*Myzus persicae*) trapped at Rothamsted in the season greatly exceeded numbers trapped in any of the previous seven years, and a peak occurred in the week ending 20 July. With large aphid populations, potato virus Y spread rapidly and by the end of August many experiments had nearly 100% plants showing leaf drop streak symptoms. Even isolated crops grown to provide seed for 1976 suffered aphid attack and by the end of August the King Edward crop showed about 10% leaf drop streak and, for the first time since 1967, has had to be rejected. No leaf drop streak was seen in the Pentland Crown seed crop. (Govier)

Survey of diseases of seed tubers. In 1974–75, King Edward stocks had the most gangrene since the survey started in 1962, and after uniform wounding one-third of all tubers developed the disease. Skin spot and black scurf were also more prevalent than usual, but powdery scab and common scab were of average occurrence and for the sixth consecutive year few tubers were affected with blight. Although the survey was started to investigate the prevalence of diseases in seed, it can now be used to measure changes in seed health resulting from the introduction of stem cutting propagation into seed production. Of 50 King Edward stocks examined in 1974–75, 24 were derived from stem cuttings (FS 1–3 certificates) and 26 not, and on average, diseases were equally prevalent in seed from both sources. These results are disappointing and indicate that at present ware producers can expect few benefits in seed health from the introduction of stem cutting propagation into seed production. Also they indicate the urgency of finding supplementary methods to maintain the health of seed during multiplication. (Hide and Bell)

TABLE 17

Survey of fungal diseases of seed tubers (percentage of tubers infected/percentage of stocks with infected tubers)

Examined		King Edward	Pentland Crown
R	Skin spot (*Oospora pustulans*)	52/96	35/92
P	Gangrene (*Phoma exigua*)	12/68	6/64
P	Dry rot (*Fusarium solani*)	3/42	7/64
R	Blight (*Phytophthora infestans*)	<1/8	<1/2
R	Black scurf (*Rhizoctonia solani*)	35/98	32/94
R	Powdery scab (*Spongospora subterranea*)	20/90	3/40
R	Common scab (*Streptomyces scabies*)	29/90	16/98
Number of stocks examined		50	50

R, examined at receipt
P, examined at planting

Electron microscopy and other services

Some of the most expensive equipment in the Department, such as the transmission electron microscope (EM), the scanning electron microscope (SEM), and the Quantimet 720 D Image Analysing Computer (QTM) are grouped in this section, and they provide a service not only for various Departments at Rothamsted, but also for other Institutes

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and organisations within and outside the Agricultural Research Service. The operation of this equipment requires a high standard of photographic presentation; recent increases in number of instruments and number of users have correspondingly increased the demand for our photographic services.

The Quantimet 720 D Image Analysing Computer. After an initial development period (*Rothamsted Report for 1974*, Part 1, 216) the QTM has been used increasingly for many varied projects:

Droplet sizing and counting. Collection efficiencies of vertical and horizontal leaves in barley and wheat crops have been estimated by dispersing fluorescent droplets about the size of mildew spores and counting the number caught by the leaves, using the QTM. (Jones and Bainbridge.) Droplet sizes in sprays used on crops have also been measured. (Turner, with Arnold, Insecticides and Fungicides Department)

Leaf area measurements. The QTM is used routinely for measuring leaf areas of sugar beet (Turner with Jaggard, Broom's Barn) and of different species of Gramineae. (Turner, with Dr. D. Coupland, Weed Research Organisation)

Particle sizing and counting. The QTM gives a faster and more accurate measurement of particle sizes in soils than can be obtained by sieving (Turner, with Dr. B. D. Soane, NIAE, Scotland). It has also been used to measure particle sizes and their distribution in Kaolin powders. (Turner, with Jeffs, Insecticides and Fungicides Department)

Land use classification. Areas of different land classifications were measured for the Trans Perak region of Malaysia using maps supplied. (Jones and Turner, with Bolton, Chemistry Department (see page 98))

Cuticular wax on leaf surfaces. Fresh frozen leaf tissue was photographed on the scanning electron microscope and the QTM was used to measure the area of leaf surface covered by cuticular wax, since it seemed likely that susceptibility to leaf pathogens depended on the amount of wax protection (see page 265). (Turner and Rawlinson)

Pea moth antennae. To try and relate specific function of hairs on pea moth antennae to their size and shape, the QTM was used in conjunction with phase contrast microscopy to measure sizes of individual hairs on an antenna. (Jones and Turner, with Wall, Entomology Department)

Electron microscopy. In addition to routine work on virus research, the electron microscopes have been used on other work, including:

Physiological leaf speckle of wheat. Ultra-thin sections of wheat leaf cv. Cappelle, have shown the presence of subcuticular fungal hyphae in the light 'speckled' areas of the leaf, a symptom known at Rothamsted as 'Spotted Dick'. (Jones and Jenkyn)

Ultrastructure of virus-infected leaves. Changes in ultrastructure following virus infection have been studied in cassava (cassava mosaic virus) and *Commelina* sp. and *Aneilema* sp. (undescribed viruses). Ultra-thin sections of *Erlangea* (yellow net) and groundnut (rosette) were used in an attempt to find the causal agents of the diseases. (Jones, with Dr. K. R. Bock, EAFFRO)

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Ultrastructure of Pea Moth antennae. In an attempt to identify the pheromone receptor of the moth, thin sections of Epon-embedded antennae and scanning electron microscopy revealed a number of anatomically distinct hairs. (Jones and Turner, with Wall, Entomology Department). (For details see Entomology Department Report, p. 124.)

Gold coating frozen specimens for scanning electron microscopy. The freezing of specimens for examination in the scanning electron microscope (SEM) offers many advantages over other preparation techniques. However, artefacts produced by electrical charges are difficult to control when using uncoated specimens, and so we deposit a gold coat on frozen specimens, keeping them frozen during the procedure, and examine them frozen using a cooling stage in the SEM. The device for gold coating consists of a copper block fitted to an Edwards E12E coating unit. The block is cooled by circulating liquid nitrogen (LN_2). Specimens are attached to stubs, on a copper specimen block covered by a lid and cooled in LN_2. This covered assembly is transferred to a cooled copper block in the evaporator and the system pumped to a vacuum of approximately 10^{-3} mmHg. The lid is removed and a gold target on a moveable arm placed over the specimen, which is coated by sputtering the gold using argon ions. After gold coating the lid is replaced and the specimen block transferred to the SEM under LN_2. (Turner and Jones, with Minter, Instrument Workshop)

Staff and visiting workers

J. M. Hirst resigned in July to take up a new appointment as Director of Long Ashton Research Station and Professor of Agricultural and Horticultural Science in the University of Bristol. He joined the Plant Pathology Department at Rothamsted in 1950, became Head of Department in 1967 and was promoted to Deputy Chief Scientific Officer in 1971. He was awarded the Jakob Eriksson Gold Medal in 1959 for outstanding work in plant pathology and mycology, and in 1970 was elected a Fellow of the Royal Society and awarded the Research Medal of the Royal Agricultural Society of England. With his wide interest in plant pathological problems and awareness of the needs of agriculture he encouraged many new lines of work in the Department, but he is best known for developing the science of aerobiology and using it to study the epidemiology and control of foliar pathogens. Much of his work depended on information provided by the 'Hirst' spore trap, which he developed during his earlier days at Rothamsted and which is now used all over the world to study the aerial distribution of agents ranging from plant pathogens to respiratory allergens.

E. Lester, Assistant Secretary of Research Division I (Plants and Soils) at the Agricultural Research Council Headquarters, succeeds Hirst as Head of Department from 1 February 1976; meanwhile G. A. Salt is acting Head.

During the year R. I. Harris was appointed to a research post financed by the Potato Marketing Board and Philippa Legg and E. W. Broom resigned. Marilyn Kemp, Barbara Rankin, Rosemary Vine, D. C. Earnshaw and J. Warrack worked as sandwich course students from April to September.

Visiting workers included Dr. R. D. Graham (The Waite Institute, Australia), Professor T. P. Pirone (University of Kentucky, U.S.A.), Dr. S. Barbargallo (University of Catania, Italy), Mr. J. A. O. Medaiyedu (Imperial College and Nigeria).

R. A. Hill was awarded a Home-Grown Cereals Authority Grant, B. D. L. Fitt continued as an Agricultural Research Council student and P. T. Gans with a post-graduate studentship from the Potato Marketing Board. Dr. P. H. Gregory continued working at the invitation of the Lawes Agricultural Trust.

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S. J. Eden-Greene continued his work in Jamaica on lethal yellowing of coconut for the Ministry of Overseas Development, but two others returned from secondments abroad, R. H. Kenten from Ghana and A. J. Dabek from the Solomon Islands.

J. M. Hirst and D. Hornby attended the 'Third Conference on Pathological Organisms in Cereal Monoculture' at Gembloux and Wépion, Belgium (European and Mediterranean Plant Protection Organization, EPPO). D. H. Lapwood attended a conference on 'Bacterial and fungal diseases of potatoes', Brussels, Belgium, also organised by EPPO, and C. J. Rawlinson attended the 'Third International Congress of Virology' in Madrid. D. Hornby visited the Phytopathologisch Laboratorium, 'Willie Commelin Scholten' Baarn, The Netherlands, and attended a planning group for the programme on 'Soil-borne Pathogens' for the Third International Congress of Plant Pathology (Munich, 1978).

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