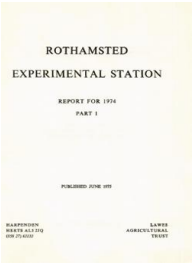
ROTHAMSTED RESEARCH

Report for 1974 - Part 1

Full Table of Content



Plant Pathology Department

J. M. Hurst

J. M. Hurst (1975) *Plant Pathology Department ;* Report For 1974 - Part 1, pp 211 - 244 **- DOI: https://doi.org/10.23637/ERADOC-1-131**

PLANT PATHOLOGY DEPARTMENT

J. M. HIRST

Staff

Head of Department J. M. Hirst, D.S.C., PH.D., F.R.S.

Senior Principal Scientific Officer
B. Kassanis, D.SC., F.R.S.

Principal Scientific Officers
A. J. Cockbain, PH.D.
D. A. Govier, PH.D.
G. A. Hide, PH.D.
D. Hornby, PH.D.
R. H. Kenten, O.B.E., D.SC.
J. Lacey, PH.D.
D. H. Lapwood, PH.D.
I. MacFarlane, PH.D.
G. A. Salt, PH.D.
D. B. Slope

Senior Scientific Officers
D. J. Austin, PH.D.
A. Bainbridge, PH.D.
J. M. Carpenter, PH.D.
J. F. Jenkyn, PH.D.
R. T. Plumb, PH.D.
C. J. Rawlinson, PH.D.
O. J. Stedman
R. D. Woods

Higher Scientific Officers
M. J. Adams, PH.D.
F. Bell
E. W. Broom, M.I.BIOL.
A. J. Dabek, PH.D.
S. J. Eden-Green, B.SC.
M. E. Finney, PH.D.
R. W. Gibson, PH.D.
D. R. Henden
P. Jones, B.SC.
G. H. King, N.D.H.
R. D. Prew, B.SC.
R. H. Turner, B.SC.
R. F. White, B.SC.

Scientific Officers
Mrs. Roberta Bowen, B.SC.
Mrs. Philippa R. Legg, B.SC.
Mrs. Elizabeth A. Lennon
Mrs. Sheila E. L. Roberts
Janet E. Smith, B.SC.

Assistant Scientific Officers
June Y. Barry
Mrs. Pamela Evans
R. J. Gutteridge
Lynda Hadnutt
Mrs. Hilda M. Instance, N.D.H.
G. Muthyalu, M.SC.
D. W. Roberts
Mrs. Heather M. Rushforth, B.SC.
C. B. Smith
A. Strowman
Janis Taylor
B. Webster
Mrs. Hilary G. Wilson

Temporary Workers
B. D. L. Fitt, B.A.
P. T. Gans, B.SC.
P. H. Gregory, D.SC., F.R.S.
R. A. Hill, B.SC.
T. P. Pirone, PH.D.

Secretary
Mrs. Stella E. V. Stevenson

Shorthand-typists
Mrs. June M. O'Sullivan
Mrs. Audrey Allen

Laboratory Attendant
S. Forde

Summary

If it is true that no year is average, there must also be few so abnormal as 1974. It began with yet another in a sequence of mild winters that allowed good planting, then followed a dry spell that ended just before crops suffered irreparable damage. The weather then became progressively wetter as summer passed to autumn and winter. Potato experiments perhaps suffered most, not only because lifting was so delayed (p. 237), but because weather at first too dry to encourage bacterial spread gave place to deluges in which they spread so ubiquitously that the directions, distances and quantities of movement were no longer discernible (p. 238). Nevertheless, the consequences among stored crops may prove interesting (p. 241). Harvest of field bean experiments was also much delayed and the results were less accurate than usual (p. 235). However, during the 'Subject Day on Field Beans' on 25 June, the growing crops helped demonstrate that insecticides may be useful for decreasing spread of weevil-transmitted viruses (p. 235) and confirmed the value of sowing only healthy seed; a commodity we hope can eventually be made common

https://doi.org/10.23637/ERADOC-1-131

enough to permit an official health certification scheme. Success probably depends much on understanding the biology of the main vector *Apion vorax* of which we learnt much (p. 236), including the suggestion that their apparent distaste for peas may protect this crop from these viruses (p. 236).

Although many cereal crops looked sad before harvesting, most escaped the worst of the wet weather. Indeed, one experiment failed early because dry weather and growth equalised almost a tenfold difference in *Rhynchosporium* infection on barley drilled after ploughing or directly into unburnt stubble (p. 239). Even so, elsewhere we often measured more than 10^8 *R. secalis* spores/30 cm of barley row (p. 222). By contrast, the weather favoured barley mildew and one well-timed tridemorph spray increased yield by 26%, however, this was much less than the 40% increase achieved by uneconomic fungicide applications in the same experiment (p. 220).

The rainfall distribution also proved interesting in a take-all experiment at Woburn, where disease made less difference to soil moisture profiles during the earlier, drier months than shortly before harvest (p. 218). The possibility of defining periods when root damage matters most and even of estimating root activity and seasonal transpiration by silicon analysis (p. 219) offers hope that more accurate ways of assessing diseases may eventually be found (p. 216). Elsewhere in the report (p. 228) we emphasise efforts to compare fungi reported as causing take-all in different countries, the viruses they contained and the fungi with which they are associated. Data from several Rothamsted experiments now support the assertion that the rate of take-all increase is slowest following grass, where it was usually associated with more *Phialophora radicicola* var. *graminicola* (p. 226).

The work on grass viruses began to provide information (p. 231) on the occurrence of ryegrass mosaic virus, the mites that transmit it and how both may be affected by sward management. The acaricide endosulfan proved more effective than we expected so we shall test further whether fewer, well-timed sprays could be both profitably and safely used. Fortunately fungal diseases were less conspicuous on swards than viruses, because the small effort we can so far contribute to studying these remains unsatisfactory (p. 233).

After having written last year that 'scourges such as sugar beet yellows and aphid-transmitted potato viruses are no longer causes of serious loss', it is disappointing to have to admit that in 1974 both were damaging and exceptionally prevalent (p. 241). The mild winter that favoured *Myzus persicae* also favoured the *Macrosiphum euphorbiae* that caused widespread top-roll on potatoes (p. 241) and the cereal aphids that made barley yellow dwarf virus more than usually abundant (p. 220). It was purely coincidental that in the year when sugar beat suffered so much from aphid transmitted viruses, we began re-examining these viruses (p. 213) and also learnt how to improve the ability of aphids to transmit tobacco mosaic virus in artificial systems (p. 213). Such a year must shatter complacency among plant pathologists and we hope stimulate efforts to understand better how to control aphid transmission of viruses (p. 220) or virus multiplication with potential inhibitors (p. 213).

Properties of viruses and virus diseases

Multiplication of TMV in tobacco protoplasts. When describing simpler methods for preparing and infecting protoplasts (*Rothamsted Report for 1973*, Part 1, 116) we said $CaCl_2$ was essential. Later work has shown that virus multiplication was inhibited by antibiotics used to stop bacterial and fungal growth and that $CaCl_2$ and salts of other divalent metals, especially $MnCl_2$, prevent this inhibition.

Several antibiotics decreased TMV multiplication at any time during the first 24 h after infection but none so completely as gentamicin, which had a large effect when present for only 1 or 2 h immediately after infection or 2 h later. Gentamicin is produced

https://doi.org/10.23637/ERADOC-1-131

by the actinomycete *Micromonospora purpurea*. Unlike some other virus inhibitors produced by microorganisms or extracted from plant sap, gentamicin did not inhibit the infection of tobacco plants. By contrast sap from Sweet William plants (*Dianthus barbatus*) which does inhibit whole plant infection, also inhibited virus multiplication in protoplasts but $MnCl_2$ did not prevent this inhibition. It therefore seems likely that the inhibitory mechanism in protoplasts may differ from that in whole plants. Chelating agents, such as 1 mM EDTA or 5 mM potassium citrate, also proved strong inhibitors of virus multiplication in protoplasts but their inhibition was prevented by $MnCl_2$. Possibly therefore antibiotics like gentamicin may chelate metals from the protoplast membrane, thus disorganizing it and affecting virus multiplication. (Kassanis, White and Woods)

A transmission component for potato virus Y (PVY). Attempts to characterise the comnent in sap that aphids need before they can acquire PVY from pure solutions, were hindered by the lability of the component in plant extracts. However, the component can be precipitated from plant extracts with 6% polyethyleneglycol (mol. wt. 6000) and resuspended in buffer solutions containing magnesium ions. Such preparations lost little activity when kept for two days at 4°C, or longer when frozen. The component was concentrated 100-fold by two successive precipitations with 6% polyethylenegylcol. Further fractionation was achieved by 'Sephadex' gel filtration and reconcentration of the active fraction by precipitation. Physicochemical and serological studies of these purified preparations should show whether the component is free virus protein or a distinct virus-induced substance. (Govier and Kassanis)

Aphid transmission of TMV. The efficiency with which aphids can transmit TMV mixed with poly-L-ornithine by feeding through membranes (Pirone & Shaw *Virology* (1973) **53**, 274–276) has been increased by using methods found satisfactory for PVY (*Rothamsted Report for 1972*, Part 1, 123). When fed on TMV mixed with poly-L-ornithine, 100 aphids (*Myzus persicae*) consistently produced 10–25 lesions on tobacco (cv. Xanthi-nc). This transmission was not through abrasions from claws, because aphids from which these were removed transmitted almost equally. Among six polycations tested, only poly-L-ornithine and poly-L-lysine made TMV aphid-transmissible. Efficiency varied with molecular weight, poly-L-ornithine (mol. wt. 120 000) was better than poly-L-lysine (mol. wt. 85 000) and poly-L-lysine of mol. wt. 30 000 or 15 000 were ineffective.

Aphids fed first on poly-L-ornithine and then on TMV transmitted infrequently and only when a high concentration of poly-L-ornithine was used. This suggests that the mechanism may differ from that between PVY and its helper component. (Pirone and Kassanis)

Beet yellows virus (BYV). Virus from sugar beet was transmitted by *Myzus persicae* to *Claytonia perfoliata*, a host in which it causes stunting, some yellowing, systemic necrosis, wilting and in which the virus occurs in unusually high concentration. Two weeks after infection sap from *C. perfoliata* leaves was extracted by grinding in a mortar with 0·1 M ammonium acetate pH 7·0, containing 0·02 M EDTA and 0·02 M DIECA (3 ml/g. leaf). The sap was clarified by centrifuging, stirred for 30 min with 2·5% Triton X-100 and twice centrifuged for 2 h at 20 000 g. Each time the pellets were suspended in 0·001 M borate buffer pH 7·8 and clarified. The final preparations gave one peak in the analytical ultra-centrifuge (142 S) and contained particles averaging 1250 nm long. The first supernatant was re-centrifuged for 90 min at 110 000 g and yielded as much virus as the first pellet, but the particles were more fragmented and gave two peaks in the analytical ultra-centrifuge (119 S and 142 S). The virus sedimented at 20 000 g was more infective and

https://doi.org/10.23637/ERADOC-1-131

when inoculated mechanically caused necrotic local lesions on *C. perfoliata*. A total of 15–20 mg of virus was obtained from 100 g of leaf.

The extinction coefficient of BYV was 2·8 and its u.v. absorbance ratio, A260/A280 was 1·45–1·6. It contained 6% ribonucleic acid with a molar base composition 19% U, 24% C, 30% A and 27% G. This suggests the virus protein contains unusually little, if any, aromatic amino acids. The molecular weight of the protein, estimated on 5 and 10% SDS acrylamide gels, was 22 000 in contrast to 30 000–34 000 usual for other flexuous rod-shaped viruses. (Kassanis, Carpenter, White and Woods)

Festuca mottle virus (FMV). The virus (*Rothamsted Report for 1973*, Part 1, 137) was extracted from pot-grown oat plants one month after inoculation. Leaves were macerated in water, 0·1 M ammonium acetate buffer pH 5·2 or 0·1 M sodium borate pH 8·0, filtered, clarified by emulsifying with chloroform and the virus concentrated from the aqueous phase with several cycles of differential centrifugation. Virus solutions containing buffer and 0·02% sodium azide stored for at least 6 months at 5°C.

The particles (isometric 26–28 nm) mostly seemed 'empty' when fixed in potassium phosphotungstate but all appeared full when initially fixed with formaldehyde. However, the analytical ultracentrifuge usually showed only one component 118 S, occasionally with small amounts of dimer 147 S. Analysis on 5 and 10% SDS-acrylamide gels revealed only one type of protein and gave closely similar estimates of mol. wt.; respectively 26 800 and 27 000. The u.v. absorption spectrum is typical of a virus containing 20% RNA.

An antiserum prepared to FMV had a titre of 1/4096 in precipitation tests and gave a single sharp line in double diffusion tests at dilutions as great as 1/1024. However, it did not react in double diffusion tests with brome mosaic or with a group including cocksfoot mottle, tobacco necrosis, cucumber mosaic, turnip rosette or sowbane mosaic viruses, which show only one component in the analytical ultracentrifuge and have proteins similar in molecular weight. Brome mosaic virus antiserum did not react with FMV but antiserum to cocksfoot mild mosaic (CMMV) gave a single line down to 1/64 (homologous titre 1/1024). CMMV is reported only in Germany but is serologically related to phleum mottle virus (PMV) which occurs in Britain. Unlike FMV, CMMV and PMV do not infect oats which should be a useful diagnostic host. (Carpenter and Gibson)

Oat sterile dwarf virus (OSDV). Thin sections of oats and ryegrass with OSD showed virus particles about 70 nm in diameter, with a light staining wall surrounding a dense core (50 nm diameter). Such particles, not previously recorded in Britain, support the virus etiology of the disease and confirm the 73 nm spheres found in OSD leaf enations by Brcak and Kralik in Czechoslovakia. We found particles in phloem, sieve cells and perivascular parenchyma, usually individually but sometimes in paracrystalline arrays. (Dabek and Plumb)

Virus diseases of tropical crops

***Viruses infecting taro* (Colocasia esculenta).** In addition to dasheen mosaic (DMV), alomae and bobone, two other virus-induced syndromes are recognised on taro in the British Solomon Islands Protectorate (BSIP). One comprises plants that are temporarily stunted and show a mosaic on leaves that become convex and wrinkled. These contain the small bacilliform particle component of alomae (Kenten & Woods, *PANS* (1973) **19**, 38). Both types of taro (known in BSIP as 'males' and 'females', although these names have no sexual significance) were affected. The second syndrome occurred only on 'male' cultivars, was transient and associated with only the large bacilliform particle which is associated with both alomae and bobone. Affected leaves were scarred, wrinkled and sometimes had enations on the petiole.

https://doi.org/10.23637/ERADOC-1-131

Elsewhere, the small bacilliform particle occurred in diseased taro from Papua—New Guinea but three cultivars from Kenya and one from Ghana were symptomless. At least one Kenyan cultivar was not resistant, because it became infected with DMV and the large bacilliform particle when infested with aphids and planthoppers from a diseased BSIP plant. (Dabek and Plumb)

Insect transmission of taro viruses. Tests in BSIP suggest that the taro planthopper *Tarophagus proserpina* can transmit both the large and small bacilliform particles from plants showing alomae symptoms. By contrast, in Rothamsted glasshouses, *T. proserpina* seems only to transmit the larger particle, because when fed first on plants with alomae and then on 'female' plants they transmitted only bobone and sometimes large particles to 'males'. We have also failed to transmit small bacilliform particles with *Planococcus citri* and *Aphis gossypii*. At Rothamsted *T. proserpina* seemed slower than in BSIP to acquire the large particle, respectively 5 and 2 days, and to transmit it, 22 and 18 days. Taro seedlings are now being grown to confirm our apparent success in transmitting the large particle, because it is conceivable that the 'female' test plants could have retained large bacilliform particles after recovering from previous bobone symptoms. Although *A. gossypii* transmitted DMV in the non-persistent manner after a five minute feed, *Myzus persicae* and *Rhopalosiphum padi* did not.

Ultrathin sections were cut of salivary glands of *T. prosperpina* fed on plants with alomae in the hope of locating bacilliform particles. None were found but there were spherical particles (60 nm diameter) with a core (30 nm) that stained much more densely than the surrounding wall. These may be an unrecorded insect virus. (Dabek)

Biodeterioration

Moulds of cereals

During growth. Bacteria, yeasts (including Sporobolomyces) and *Cladosporium* spp. again (*Rothamsted Report for 1973*, Part 1, 120) dominated the microflora of developing barley grain. Although *Penicillium* spp. often become very numerous during storage, they comprised merely 2% of the microbial population before harvest. Nevertheless several of the species important under various conditions of storage were present, for example, *P. brevi-compactum*, *P. chrysogenum*, *P. cyclopium*, *P. digitatum*, *P. funiculosum*, *P. hordei*, *P. piceum*, *P. pulvillorum*, *P. roqueforti* and *Talaromyces thermophilus* (*P. duponti*). Repeated applications of broad-spectrum fungicides (benomyl and captafol) decreased the microflora by a third and delayed senescence by up to 10 days but only slightly increased yield and did not repay their cost. (Hill and Lacey)

The development of potentially toxigenic *Fusarium* spp. was followed on wheat, oats and barley. Their incidence was doubled by lodging, increased less by much nitrogen fertiliser and not at all (in this wet season) by irrigating. Four wheat varieties were sampled from variety trials repeated on land with and without foot and root diseases. On both, Maris Huntsman and Maris Fundin had slightly more *Fusarium* than Cappelle-Desprez, while Maris Freeman varied inconsistently. Heavy nitrogen fertiliser increased *Fusarium* but the growth retardant chlormequat chloride (CCC) and the fungicides tridemorph and carbendazim had little effect. The commonest species was *F. culmorum*, with *F. avenaceum* common and *F. poae* and *F. tricinctum* occasional. (Lacey)

During storage. Grain harvested in 1973 only heated spontaneously if it contained more than 20% water or was drier but contained many immature grains resulting from early lodging. The *Aspergillus glaucus* group predominated in grain with 15 to 25% water but was maximal at 22%. *Penicillium* spp. were few below 18% water and maxi-

https://doi.org/10.23637/ERADOC-1-131

mum at 21% water. At first *P. funiculosum* was dominant but was replaced by *P. piceum* in heated grain, both were accompanied by several other *Penicillium* spp. Few samples were tested for toxicity using fertile eggs but several, including one dominated by *P. roqueforti*, decreased the hatch from 70% to 10 or 20%.

When spontaneous heating of small samples was prevented in controlled environments, *P. cyclopium* dominated at 20% water and 3–5°C but *P. viridicatum* at 25–30% water and 10°C. Increasing the temperatures in grain at 20% water encouraged first *A. glaucus* and then *A. candidus* to replace *P. viridicatum*. (Hill and Lacey)

In dust from Canadian grain elevators. Respiratory disease was found in 75% of workers in grain elevators (Tse *et al*, *Archives of Environmental Health* (1973) **27**, 74–77). Dust samples impacted on malt extract agar plates in an Andersen Sampler showed that almost all the 60 sources contained *Penicillium* spp. and surprisingly abundant yeasts, while over three-quarters contained *Aspergillus*, *Absidia*, *Rhizopus* and *Cladosporium*. Where many thermophilic fungi occurred the dusts were also examined for actinomycetes. Most samples contained *Thermoactinomyces vulgaris*, grey *Streptomyces* spp. and *Actinomadura* spp. but the only species numerous were *S. albus* and *S. griseus*. Although these samples came from Canada, a similar microflora might be expected in silos elsewhere. (Lacey, with Dr. K. S. Tse, University of Manitoba, Canada)

Preservation of pressed potato pulp. Propionic acid can be used to prevent moulding of mechanically dewatered potato pulp, see p. 89. (Lacey, with Pirie, Chemistry Department)

Mould degradation of propionic acid Small applications of propionic acid to preserve hay and other substrates are known to favour the development of *Paecilomyces varioti*, a mould, shown on p. 159 to degrade propionic acid. (Lacey, with Lord, Chemical Liaison Unit)

Measuring the effects of plant diseases

Few aspects of plant pathology are more necessary or more difficult than measuring disease losses. Studies recently begun are concentrated first on the direct effects of pathogens on their hosts, although we are aware how the economics of agriculture can alter, or by changing glut to shortage even occasionally invert, the cost of diseases. Our work aims both partially to automate measurements and to divert attention from the traditional measurement of pathogen prevalence, which is often very indirectly related to loss, towards measuring the residual activity of the diseased host, because it is the host that determines yield.

Application of Image Analysis. The 'Quantimet 720D Image Analysing Computer' (Metals Research Ltd., Melbourn, Herts.), delivered late in 1973, is capable of rapid measurement of geometric features of different optical densities and classifying them in images derived from film, photographs or light and electron microscopes. With biological material the difficulties lie in modifying existing techniques to give images with much contrast. During 1974, much effort was given to developing photographic techniques to enable the great potential of the instrument to be applied to measurements that were previously difficult or impossible to make. The problems being studied include some that present little difficulty, such as measuring leaf areas, the lengths of root fragments, counting and sizing particles or spray-droplets and others that present special problems such as large pores when analysing the pore-size distribution from soil sections.

https://doi.org/10.23637/ERADOC-1-131

To apply image analysis to plant pathological problems, methods are being developed to ease and speed growth analysis of various crops and to measure more accurately areas occupied by fungal pustules or lesions. High-speed black and white infra-red film seems to produce the best contrast between plant and soil in overhead photographs used to estimate ground cover during the early stages of crop growth. Side-view photographs of single crop rows have been used later in the season to measure growth and to estimate the filtering efficiency of crops to spore clouds passing through them. It is hoped also to use the Quantimet to estimate the pustule area per plant and to relate this to counts of spores produced. This should provide not only a means of comparing the susceptibility of different cereal varieties, but also data that might, for the first time, permit a reasonably accurate estimate of the strength of spore sources from unit areas of crop.

Considerable time has been spent attempting to measure disease incidence and severity from infra-red Ektachrome ('false colour'), aerial photographs of Rothamsted experiments. It usually seems necessary to separate bands of different spectral sensitivity by preparing black and white photographs of the 'false-colour' positive through red, green or blue filters before Quantimet analysis. Unfortunately it is difficult to eliminate variations in density due to differences in sun angle, shade from trees and other topographical features and to relate the measurements to disease severity or loss, let alone to use the measurements for prediction. At present it seems unlikely therefore that we can use aerial photography for quantitative disease surveys. (Finney, Jones, Turner and Evans, with numerous collaborators)

It is difficult to assess disease severity from the spectrum reflected by a crop to an aircraft but it may be easier to relate diseases to the spectrum from individual plots and leaves. A portable instrument is being constructed to measure the proportion of particular wavelengths incident on a crop which are reflected, without being influenced by changes in incident light intensity. It should be in use during 1975. (Finney, Jones and B. Minter, Electronic Workshop)

Effects of foliage fungi. Barley mildew (*Erysiphe graminis*) was chosen for study because it is damaging, frequent, responsive to host nutrition and alters the plant's metabolic and development processes. Mildew induces premature senescence of barley leaves and consequently reduces the photosynthetic area of the crop. The rate of senescence induced in several barley varieties by different intensities of mildew was studied in the hope that it might partially explain the relation between mildew and yield decrease. There is some evidence that 5% of a leaf must be infected before it quickly senesces but little evidence of differences between varieties.

To simulate the effects of senescence of infected leaves on plant growth, the lower leaves were removed from mildew-free plants in a glasshouse experiment. Most defoliation experiments with cereals have concerned the physiology of grain filling or effects of diseases that quickly kill localised areas of leaves. Mildew infection probably has more insiduous effects by slowly rendering leaves inactive photosynthetically, the rate depending on the intensity of infection.

Plants were maintained with one, two, or three young fully expanded leaves by necessary weekly defoliations. Additional plants were introduced to each defoliation regime on each of the nine cuttings dates. Seventeen weeks after sowing, the dry weights of shoots and roots were measured, and records made of tiller number, spikelet number and their developmental stage. Defoliating to three fully expanded leaves at any time did not harm the plants. Leaving only two or one expanded leaf increasingly limited growth of roots even at a late growth stage. Shoot dry weight was reduced most by early defoliation.

https://doi.org/10.23637/ERADOC-1-131

The more severe or prolonged the defoliation, the greater was the reduction in the number and speed of development of tillers and spikelet primordia. (Finney)

Nutrient and water uptake by healthy and diseased wheat roots. This work partly continues and develops useful collaboration begun three years ago with the ARC Letcombe Laboratory, to test the value of labelled isotope methods in both laboratory and field experiments.

Laboratory experiments. Studies of the translocation of ions through roots with take-all lesions (*Letcombe Laboratory, Reports: for 1972*, 16–19; *for 1973*, 28–29) showed decreased uptake and translocation of P, K and Ca. The uptake by whole root systems seems to depend on the severity of disease and little difference had been found between healthy roots and those with about 18% of root axes with lesions (Hornby & Goring, *Annals of Applied Biology* (1972) **70**, 225–231) or, recently, in hydroponic culture with 74% of roots with lesions. However, when 93% of root axes were infected in sand culture there were decreases both in the percentage of P and K in the shoots and the amount of P and K translocated from the roots to the shoots in a triple label (^{32}P, ^{42}K, ^{45}Ca) experiment. Within the roots, diseased plants had more P and N, but less Ka nd Mg than healthy plants. It is possible that ion uptake would be affected, in plants growing in soil, if 74% of their roots were infected, because they would usually be exposed to changes in available water and nutrients that do not occur in hydroponic culture. It may not be possible to reconcile the results of different workers until ion uptake has been compared in individual roots and complete root systems in a wide range of conditions and disease severities. (Fitt and Hornby)

Field observations. Plots of Cappelle-Desprez winter wheat with and without take-all have been examined on sandy loam at Woburn for three years (Experiment W/CS/98). This summary is based on average differences between healthy and various diseased plots; for previous results see Part 1 of *Rothamsted Reports for 1972*, p. 127 and *for 1973*, p. 123. Growth measurements such as straw length, ear number, total dry weight and P content were about 20% greater in healthy plots than in diseased (Table 1), but grain yield was 65% greater. The difference developed between growth sampling (2 July) and harvest and reflects the inability of infected plants to take up sufficient water during grain formation, despite moist soil.

TABLE 1

Incidence of take-all, growth and yield of Capelle-Desprez wheat. Woburn, 1974

	No take-all plot	Take-all plot	Ratio $\frac{\text{No take-all}}{\text{Take-all}}$
% plants infected 6 May	0	53	—
% straws with severely infected roots 2 July	0	42	—
Dry weight (g/m^2) 2 July	795	634	1·25
Phosphorus in tops (g/m^2)	1·82	1·50	1·22
Length of straw (cm)	89	75	1·19
Ears (No/m^2)	337	270	1·22
Grain (t/ha)	4·90	2·97	1·65

Soil moisture deficit profiles measured each week with a neutron probe show (Table 2) that by 2 July the deficit had increased more under healthy than diseased wheat at all depths, and between 2 and 30 July it continued to decrease under healthy wheat but decreased only in the top 10 cm under diseased wheat, and part of this was probably

https://doi.org/10.23637/ERADOC-1-131

through evaporation. By contrast the uptake of ^{32}P injected at different depths on 6 May and measured in plants sampled on 2 July was not significantly decreased by disease at any depth down to 60 cm, although the total amount taken up by diseased plants was significantly less. Presumably much of the phosphate had been taken up before take-all seriously affected root activity. Disease affected yield mainly by restricting water and nutrient uptake during grain formation, by which time roots had become extensively rotted. (Salt, with Dr. F. Ellis and Mr. K. R. Howse, Letcombe Laboratory, Wantage)

TABLE 2

Soil moisture deficits in Cappelle-Desprez wheat. Woburn, 1974

	No take-all		Take-all	
Depth (cm)	2 July	30 July	2 July	30 July
	(arbitrary units*)			
10	6·69	16·85	5·24	10·44
20	8·71	14·12	6·06	6·20
30	9·30	10·85	6·50	4·39
40	8·41	9·39	5·82	4·62
50	7·57	8·86	4·94	4·72
60	7·20	8·54	4·32	4·44
70	6·46	7·98	3·41	3·72
80	5·72	7·41	2·50	2·99
90	4·76	6·51	2·19	2·69
100	3·79	5·60	1·88	2·39
Total:	68·61	96·11	42·86	46·60

Rainfall 6 May–2 July: 104·6 mm on 20 days
3 July–30 July: 32·9 mm on 14 days

* Based on neutron probe measurements.

Australian work (Hutton & Norrish, *Australian Journal of Agricultural Research* (1974) **25**, 203) showed that the silicon content of wheat glumes was related to the total water the crop had transpired. If the same applied in Britain it might be a convenient way of assessing differences in root activity consequent on diseases. Wheat glumes from the experiment at Woburn were finely ground and analysed by X-ray fluorescence spectroscopy for silicon and other elements (Table 3). Glumes from plots with severe take-all contained a little more calcium and sulphur than those from healthy wheat and a little less potassium and phosphorus. However, the ratio of silicon contents (Table 3) in glumes from healthy and diseased plants was much larger. In Australia water supply may often be the chief determinant of transpiration; in Britain its importance may be less relative to other factors but the difference in silicon contents is large and merits further investigation. (Salt, with G. Brown, Pedology Department)

TABLE 3

Analyses of wheat glumes. Woburn, 1973

Element	K	Ca	P	S	Si
	(% of dry matter)				
Not infected. (Mean of 4 plots)	1·07	0·16	0·24	0·16	4·21
Infected by take-all. (Mean of 8 plots)	0·96	0·19	0·21	0·20	2·28
	(Ratio)				
Not infected / Infected	1·11	0·86	1·12	0·82	1·84

https://doi.org/10.23637/ERADOC-1-131

Cereal diseases

Barley yellow dwarf virus (BYDV). In a summer when virus vectors were so prevalent on other crops, such as potatoes and especially sugar beet, it is interesting that fewer cereal aphids were caught. Only three of the 357 retrieved alive from suction traps infected test plants. The autumn migration of *Rhopalosiphum padi* was also small and none (of 42 caught live) was infective. These factors, together with greatly decreased and delayed autumn sowing, should minimise autumn infection of crops for harvest in 1975.

Despite the small number of spring migrant aphids caught or found infective, there was more infection in spring barley crops, during 1974 than for several years. At Rothamsted (Experiment 74/R/B/10), applying phorate granules before sowing increased barley yields by 0·28 t/ha (P = 0·01). Spraying menazon in June gave no increase and in July little (0·1 t/ha). A comparable experiment at Seale Hayne, Devon showed no response to any treatment, perhaps because it was sown late or because the numbers of aphid vectors was too great for the insecticides to be effective.

Previous work has shown how early autumn sowing may decrease yields when BYDV is prevalent (*Rothamsted Report for 1973*, Part 1, 125) Table 4 shows that, without treatment, winter oats again yielded most when sowing was delayed until November. Unlike the previous experiment this difference was not overcome by applying phorate granules, or menazon at the four leaf stage or in spring. Despite the limited response to insecticides the crop yielded better than last year. (Plumb)

TABLE 4

Effects of insecticides and their times of application on yield of winter oats (Peniarth) sown on different dates: (Rothamsted Experiment 74/R/0/1)

Date of sowing, 1973 (D)	27 September	26 October	22 November
Treatment	yield (t/ha)		
Nil	6·73	7·02	7·42
phorate (P)	6·94	7·30	7·43
menazon at 4-leaf stage (M1)	6·84	6·95	7·54
menazon in spring (M2)	6·89	7·01	7·39

SED D P M1 M2 0·09 DP DM1 DM2 0·23 0·108

Powdery mildew (*Erysiphe graminis*) on spring barley

Effects on yield. Mildew soon became prevalent and severe in 1974, evidence from several experiments suggested that a warm spell, 15–20 May, much encouraged mildew development.

On 20 May the percentage area infected on the third youngest leaves of Zephyr barley was 1% but by 30 May was 12% on leaves then the third youngest. Few *Erysiphe* spores were caught until 21–23 May, when the deposit on 5 mm cylinder traps first exceeded 100/cm²/day above untreated crops. (Jenkyn and Hambling)

Single sprays of tridemorph (526 ml a.i./ha) were applied to plots of Julia barley (Experiment 74/R/B/1) on seven dates between 13 May and 12 June. The smallest yields came from sprays on 7 and 12 June (4·82 t/ha) and the largest from the spray on 23 May (5·88 t/ha), the latter being little less than the yield (6·00 t/ha) from plots sprayed three times on 13 May, 28 May and 12 June. (Jenkyn and Bainbridge)

In another experiment (74/R/B/7), where untreated Zephyr yielded 4·61 t/ha, one tridemorph spray (526 ml a.i./ha) on 20 May yielded 5·83 t/ha, an increase of 26%. This treatment proved better than an ethirimol seed dressing (c. 0·7 kg a.i./ha), 5·26 t/ha;

https://doi.org/10.23637/ERADOC-1-131 *pp 11*

ethirimol sprays (350 g a.i./ha) on 20 May or 3 June, respectively 5·37 and 5·08 t/ha; or single sprays on 3 June of tridemorph or chloraniformethan (290 g a.i./ha) respectively 5·38 and 4·94 t/ha.

Plots sprayed with tridemorph only on 20 May, produced more grain than plots planted with ethirimol dressed seed and then sprayed with tridemorph on 3 June (5·69 t/ha) or 12 June (5·57 t/ha). The very dry soil early in 1974 may have limited the uptake of ethirimol from seed and so impaired its effectiveness.

No single treatment allowed barley to give its potential yield, because the best of them (5·83 t/ha) was out-yielded both by plots sprayed twice with tridemorph, on 20 May and 12 June (6·29 t/ha) and by an uneconomic treatment with both captafol and tridemorph on 20 May, 3 June and 12 June (6·45 t/ha, 40% more than untreated barley). (Jenkyn)

The design of field experiments involving air-dispersed pathogens. Mention has already been made of experiments (74/R/B/1 and 74/R/B/7) where the timing of single tridemorph sprays considerably influenced the yield of spring barley but this was not always true and some results suggest that experiment design may have been important. Yields were taken from two similar latin squares (74/R/B/8), in one of which the plots were contiguous and in the other separated by 19 m wide strips of sprayed barley. Zephyr barley sprayed on 20 May and 3 June yielded similarly (respectively 5·51 and 5·58 t/ha) where plots were continguous, but where separated, the earlier spray was better (5·66 t/ha) than the later date (5·45 t/ha). We think the differences may result from different rates of reinfection of the early sprayed plots in the two designs. (Jenkyn, Bainbridge and Hambling).

There is no doubt that adjacent plots differing in prevalence of air-dispersed pathogens interfere with one another but effects on yield are not predictable. Traditional designs neither minimise nor measure interference. Although eliminating interference will be difficult, our designs, both random and systematic, aim to minimise it. Related work with the Field Experiments Section (see p. 133) is attempting to produce designs that will measure and equalise interference. (Jenkyn and Bainbridge)

Dispersal gradients. Profiles of the concentration and deposition of *Erysiphe* spores above and within mildew-free barley, were measured downwind from a strip of infected barley (100 m long × 4 m wide). Spore traps were operated in a transect 4 m high and extending 5 m downwind of the strip source. Large concentrations (6000/m³) of *Erysiphe* conidia entered the canopy of the uninfected trap crop but spores were so quickly removed by impaction or sedimentation that concentrations fell to 'background' amounts (300/m³) within the first 5 m of travel. Being only 4 m wide the infected strip had little effect on concentrations above the trap crop beyond 5 m downwind. *Lycopodium* spores were also released level with the top of the crop, from six point sources 1 m apart along the source strip. Most spores were deposited in the trap crop within 3–4 m; as upward diffusion also diluted the cloud above the crop the concentration gradients were very steep. (Bainbridge, Stedman and Sexton)

Isolates of* E. graminis *insensitive to ethirimol. Work elsewhere has shown that barley crops especially in S and E England may be attacked by *E. graminis* partially insensitive to ethirimol. We are attempting to define the competitive ability of such isolates, especially in the absence of ethirimol. However, it is proving difficult to define a reliable method of measuring what proportion of spores tolerate ethirimol, because the tests show great variability even within isolates, especially when detached leaves are used. (Smith, Bainbridge and Jenkyn)

https://doi.org/10.23637/ERADOC-1-131

Release of* E. graminis *spores. These spores are produced in basipetal chains from which the oldest spores are easily broken. The force necessary to detach them might come from air drag or acclerations caused by leaf movement. The evidence available suggests that none but the oldest spores are released by drag at air speeds less than 1 m/s, a velocity seldom reached in crops. High speed cinematography of leaves flapping in a wind stream of 0·6 m/s showed that accelerations of 1·0 m/s^2 frequently occur and would be sufficient to release mature spores when drag at that speed would not. (Bainbridge, with B. Legg, Physics Department)

Effects of brown rust (*Puccinia hordei*) on yield of spring barley. For details see Chemistry Department Report, p. 79. (Jenkyn, with Widdowson and Penny, Chemistry Department)

Winter barley as a source of spores of *Rhynchosporium secalis*. Every week from April to August, counts were made of *R. secalis* spores washed from the plants cut from five random 30 cm lengths of Maris Otter winter barley rows. Some samples were analysed to assess the effect of differences in stem number which was small, and the contribution of green, senile or dead leaves or stems. As the crop grew, spores were produced increasingly further up the plant. Senile leaves produced more spores than leaves that were green or long dead; stems produced an increasing proportion of the total spores, reaching 40% by mid-July.

The numbers of spores produced, by the not very severely infected crop, were prodigious. Five of the weekly estimates exceeded 10^8 spores/30 cm of row while the crop was growing and numbers rarely fell below 5×10^7 spores/30 cm until the crop was approaching harvest. After harvest spore production decreased from 10^7 spores/30 cm of row on stubble (and an approximately equal number on the corresponding number (50) of threshed straws) to 10^5 spores/30 cm early in November. At this time volunteer barley plants seem a much more prolific source because preliminary tests usually showed over $0{\cdot}5 \times 10^6$ spores/plant between September and November.

The estimates made by washing samples taken during the growing season differed by up to almost five-fold. This seemed mostly due to real differences rather than sampling errors, a conclusion supported by estimates of $2{\cdot}6 \times 10^6$ spores/stem before 23 mm of rain fell in 12 h and $0{\cdot}6 \times 10^6$ spores/stem afterwards. Although it is surprising that so many spores remained on the plants, the number removed was considerable and efforts were made to assess the wastage to soil, by collecting water dripping from plants through 4 cm diameter funnels at soil level. These suggested that for 1 mm of rain as few as 1% of the spores produced on the crop reached the ground in this way, and would account for 20% (c. $0{\cdot}6 \times 10^6$) of the spores removed per stem during 23 mm of rain. Although many of the other spores removed may travel down the stems in water films, the fate of the majority remains unexplained.

Attempts to perfect a trap for splash-dispersed spores, previously unsuccessful, gained some encouragement when a rotorod trap was modified to carry two 12·5 mm diameter discs at 2300 rpm. The largest catch, made 15 cm above ground in winter barley, was 5920 spores/disc (volume swept 7·9 m^3/h). Like most large catches this was made during a period of heavy rain (the last 40 min of a 1 h, 0·75 mm shower during early July). On a day of intermittent showers the discs were changed so that catches could be compared with rainfall; 1125, 82 and 950 spores were caught during showers of 1·7, 0·3 and 2·6 mm respectively. These catches support the indication from weekly plant washings that periods of intense rain are particularly important to the dispersal of splash-dispersed *R. secalis* spores. (Stedman)

https://doi.org/10.23637/ERADOC-1-131

Fungicides on winter wheat. Table 5 records the effect of fungicides on diseases of winter wheat (cv. Cama). Details of application are given in *Yields of the Field Experiments, 1974*. Mildew was patchily distributed on this wheat until late in the season when 'BAS 3000F', tridemorph and ditalimfos ('Dowco 199' or 'Plondrel') limited it most. Septoria, was not severe and little affected by the fungicides. Eyespot was decreased by 'R 28921' and 'NC 5936', applied as a seed dressing, but the latter killed more than half the plants, which may account for the decreased percentage incidence of eyespot. Sharp eyespot was increased by 'R 28921' but no fungicide affected take-all. (Prew and Jenkyn)

TABLE 5

Effects on diseases of winter wheat of fungicides, applied as seed dressings (SD) and, on 15 May and 19 June, as sprays (S) or granules (G)

Fungicide	Method(s) of application	% 3rd leaf area infected 12 July		% straws infected 4 July		% plants infected 4 July
		Mildew	Septoria	Eyespot	Sharp eyespot	Take-all
None	—	19·6	4·3	33	7	77
Organo Hg	SD	22·2	3·9	31	4	81
'BAS 3000 F' (BASF)	S	3·2	3·0	39	4	87
tridemorph (BASF)	S	4·1	3·8	34	12	90
'BAS 3000F' & tridemorph	S	6·6	2·5	37	10	80
ditalimfos	SD+S	6·6	3·9	45	10	84
'Kitazin P' (Kumiai)	SD+S	9·6	3·0	45	7	79
'NC 5936' (Fisons)	SD	23·6	4·3	19	2	70
'NC 5936' (Fisons)	G	19·6	3·2	39	2	83
'PP 395' (Plant Protection)	SD+S	14·0	3·9	47	10	87
'R 28921' (Stauffer)	SD+S	12·7	3·2	18	31	81
'Terrazole' (AA products)	SD	21·9	6·7	46	18	88

Take-all and other root rots. Unimpeded attacks of take-all so threaten the profitability of wheat and barley crops that farmers must plan to avoid them. An almost certain way on fertile land is to alternate these crops with others not susceptible to the disease. However, soil and markets only permit alternation with other high value cash crops on a small proportion of the land we crop with cereals. At present, on the remainder it may be more profitable to rely on low cost consecutive cropping with wheat or barley by utilising the decline in damage from take-all that occurs after the first few consecutive susceptible crops. Our aim is to provide a third possibility of profitable rotations including winter wheat crops in which the disease increases slowly. It is not difficult to find organisms that antagonise the growth of the take-all fungus in culture but so far none offers promise of enhancing or accelerating the decline of take-all among crops. However, evidence is accumulating that some fungi that seem most prevalent after grass crops may retard the increase of take-all in sequences of susceptible crops. We hope that a better understanding of such relationships may improve our ability to predict the timing and severity of take-all following various previous crops and in different soils and climates.

During 1974 our previous studies were continued but this report emphasises the complex interactions between host nutrition, cropping history and the fungi (and viruses) associated with *Gaeumannomyces graminis* var. *tritici*, the take-all fungus.

Effects of phosphate fertiliser on take-all of wheat. After six years of barley, the PK and Take-all experiment (R/CS/24 and *Rothamsted Report for 1973*, Part 1, 132) plots on West Barnfield were given renewed six-year dressings of P and annual P and K and sown to winter wheat with 126 kg N/ha. Increasing P decreased take-all (Table 6). Despite spraying the barley stubble with aminotriazole in 1973, the wheat was infested by *Agrostis gigantea*, slightly where much P and K was applied and seriously where little was given.

https://doi.org/10.23637/ERADOC-1-131

TABLE 6

The effect of phosphate and potash fertilisers on take-all and yield of winter wheat. PK and take-all experiment, West Barnfield, 1974

K manuring (kgK/ha)	P manuring, (kgP/ha*) Annually Nil	15	60	Once, autumn 1973 90	360
	% plants with take-all in July and (take-all rating)†				
30	71 (107)	60 (79)	58 (79)	61 (94)	51 (75)
120	75 (123)	78 (109)	59 (84)	64 (87)	49 (64)
	Grain yield, t/ha				
30	4·90	5·96	6·34	6·28	6·47
120	5·28	6·11	6·75	6·92	6·99
	% ground cover by *Agrostis gigantea*, August				
30	80	40	26	18	16
120	65	39	9	19	6

* All treatments received 126 kg N/ha.
† See page 225.

No grass weed occurred to complicate results from the Residual Phosphate experiment (R/RN/7) cropped with winter wheat in 1974 following a swedes, potatoes, barley rotation since 1960 (*Rothamsted Report for 1973*, Part 1, 56). Table 7 shows take-all was severe only where P was lacking. (Slope and Broom, with Mattingly, Chemistry Department)

TABLE 7

The effect of phosphate fertiliser on take-all and yield of winter wheat. Residual phosphate experiment, Sawyers, 1974

	P manuring* kgP/ha	% plants with take-all (July)	Take-all rating	Grain yield (t/ha)
None		90	184	4·80
Annually	12	14	19	7·48
	25	15	22	7·01
	49	19	28	6·91
	74	14	26	7·12
Triennially	37	39	70	6·17
(Last, spring 1972)	74	20	39	7·11
Every 6 years	148	6	6	7·41
(Last, 1972–73)	296	9	12	6·68
	444	8	19	7·39

* All plots received 126 kg N/ha + 90 kg K/ha for winter wheat in 1973–74.

Although common on Broadbalk take-all seldom severely damaged any crop when wheat was grown continuously or four of every five years. However, severe damage has occurred during 1973 and 1974 on one plot carrying a second wheat crop on a section now fallowed every third year (Plot 10, Table 8) and deficient in phosphate. Two explanations seem feasible; either more frequent fallowing decreased the factors that make take-all decline, more in soils deficient in P than in soils rich in P; or the decline factors were decreased in all soils, but take-all increased faster where P was deficient.

The second explanation was supported by results on the Residual Phosphate experiment where take-all decline was not established. If this is true, a third crop after fallow on Broadbalk now might be seriously attacked whatever the manuring, a possibility that many might wish to avoid as much as pathologists might be delighted to test. (Slope, Broom and Gutteridge)

https://doi.org/10.23637/ERADOC-1-131

TABLE 8

The effect of fallowing and fertilisers on the percentage of plants with take-all and on take-all rating (in brackets). Broadbalk wheat, 1974

	Plot 10 N2	Plot 11 N2P	Plot 13 N2PK
First wheat after fallow	1 (1)	1 (1)	0
Second wheat after fallow	78 (146)	22 (38)	10 (11)
Continuous wheat since 1967	52 (60)	13 (14)	36 (38)
Continuous wheat since 1959	42 (49)	23 (27)	44 (52)

N2, 96 kg N/ha; P, 35 kg P/ha; K, 90 kg K/ha; applied annually.

Take-all on winter wheat after ley and arable rotations. Between 1968 and 1972 parts of the two Rothamsted Ley-Arable experiments that completed their test crop cycles were 'phased-out' into consecutive winter wheat crops. In *Rothamsted Report for 1971*, Part 1, 141–143 we reported take-all development on the wheat following Series I and II, and now report similarly for Series III and IV, where the following cropping sequences were represented.

Sequence	Treatment crops	Test crops
Ah	Hay, sugar beet, oats	Potatoes, wheat, barley
Lu	Three years lucerne	Potatoes, wheat, barley
Lc	Three years grass-clover	Potatoes, wheat, barley
Ln	Three years grass with much N	Potatoes, wheat, barley
G	Permanent grass (Highfield only)	Potatoes, wheat, barley
R	Reseeded grass (sown 1948, see Table 9)	Potatoes, wheat, barley

Thus, on every plot, the first wheat of the 'phasing-out' sequence was the third successive crop susceptible to take-all (W_3) after at least four non-susceptible crops. A 'take-all rating', the sum of respectively, one, two or three times the percentage of plants slightly, moderately or severely infected was calculated (only for plots receiving 126 kg N/ha). Usually ratings above 150 are associated with enough take-all patches or whiteheads to attract farmers' attention. Table 9 shows that, as on Series I and II, such ratings occurred

TABLE 9

The effect of different crop sequences on 'take-all rating' on winter wheat, Highfield and Fosters, 1971–74

		Highfield				Fosters			
		1971	1972	1973	1974	1971	1972	1973	1974
Crop sequence		W3	W4	W5	W6	W3	W4	W5	W6
Series III	Ah	167	148	98	48	10	42	154	58
	Lu	189	99	99	38	10	56	177	94
	Lc	35	158	134	70	2	14	108	78
	Ln	112	196	150	64	1	26	87	80
	R[1]	76	206	194	102	26	58	181	124
	G[1]	40	184	149	82	—	—	—	—
			W3	W4	W5		W3	W4	W5
Series IV	Ah	b	88	124	90	b	1	54	72
	Lu	b	154	172	50	b	66	249	43
	Lc	b	28	202	60	b	1	35	33
	Ln	b	24	125	103	b	1	46	52
	R[2]	b	68	187	102	b	19	110	90
	G[3]	b	24	124	152	—	—	—	—

[1, 2, 3] Grass ploughed out in 1967, 1962, 1968 respectively.
Crop symbols: W, winter wheat; b, spring barley. Numbers after crop symbols indicate number of consecutive wheat or barley crops.

https://doi.org/10.23637/ERADOC-1-131 *pp 16*

earliest on wheat after the Lu sequence. Development on other sequences was too inconsistent to allow prediction of the onset and duration of severe attacks or their decline. For example, we cannot predict whether take-all will increase or decrease in 1975 after the Lc and Ln sequences of Series IV on Fosters.

In the hope of understanding and hence predicting better the development of take-all in consecutive susceptible crops, we estimated the infectivity of soils at different phases of the original six year ley-arable cropping cycle. Soil cores were taken from the contrasting Lu and Lc sequences (in the 'Museum' blocks of the experiment retained under treatment and test crops) on Highfield. Ten wheat seedlings/core (5 cm × 10 cm deep) were grown for 5 wk at 15–10°C (day–night) before examination for take-all. Just before the leys were sown in the spring following the last barley test crop, 68% of cores from Lu gave infections and only 6% from Lc; but at the end of the leys 2½ years later only 6% of cores from Lu and 5% from Lc were infective. Thus the differences between ley sequences lies in the increase of infectivity during susceptible test crops rather than in survival differing during the leys. In 1971 and 1974 (Table 10, GGT) we found the difference between sequences developed rapidly during the wheat, first susceptible, test crop.

TABLE 10

Infection of assay seedlings with Gaeumannomyces graminis *var.* tritici (*GGT*) *and* Phialophora radicicola *var.* graminicola (*PRG*)

	Highfield			Fosters		
Sequence	GGT[1]	PRG[1]	PRG[2]	GGT[1]	PRG[1]	PRG[2]
Lu	68	24	9	16	92	25
Lc	10	72	20	4	90	45

[1] Per cent of cores with infected seedlings.
[2] Per cent of 1 cm root pieces giving PRG on potato dextrose agar and streptomycin after surface sterilising 20 s in 1% silver nitrate and precipitating in 5% sodium chloride.

Because Deacon (*Plant Pathology* (1973), **22**, 88–94) reported that *Phialophora radicicola* var. *graminicola* was prevalent on wheat following grass and inhibited take-all infection, we estimated *P.r. graminicola* (PRG) on the roots of assay seedlings. Table 10 shows it was more prevalent in sequence Lc than in sequence Lu on Highfield but unexpectedly showed even more on both sequences on Fosters, a field with a long history of arable cropping prior to 1948. These data support the hypothesis that *P.r. graminicola* may delay the development of take-all but, unless the lucerne on Fosters contained grass weeds not present on Highfield, do not permit all its effect to be attributed to grass. (Slope, Prew and Gutteridge)

Fungi of the Gaeumannomyces-Phialophora complex on wheat and barley. When measuring the prevalence of fungi that produce runner hyphae on cereal roots we distinguish the wheat take-all fungus *Gaeumannomyces graminis* var. *tritici* (GGT) and, for convenience, the two taxa *Phialophora radicicola* var. *graminicola* (PRG) and *Phialophora radicicola* var. *radicicola* (PRR) (Deacon, *Transactions of the British Mycological Society* (1974), **63**, 307–327). It is possible that the last may be the imperfect stage of *Gaeumannomyces graminis* var. *graminis*.

Isolations were made from wheat and barley roots from experiments involving different previous cropping and P manuring. Table 11 separates the sources into two groups of wheat, with and without preceding leys, and one of barley from two extremely contrasted experiments (Hoosfield, barley almost continuously since 1852 and Barnfield, the classi-

https://doi.org/10.23637/ERADOC-1-131

cal site for continuous mangolds where during the last 100 years there have been only three previous cereal crops, in 1968, 1970 and 1972).

Adjacent 1 cm and 2 cm segments from two seminal roots from each of 50 plants were assessed for take-all lesions. The 1 cm segments were cleared in warm potassium hydroxide, stained in trypan blue and examined microscopically. The 2 cm segments were sterilised (1% $AgNO_3$, 20 s) and plated on potato dextrose agar containing streptomycin. Tables 11 relates take-all lesions, vascular discoloration and isolations of GGT to the prevalence of PRG, PRR and the different types of vesicles the latter form in roots. PRR was isolated only from roots of barley from Hoosfield, not from wheat. By contrast PRG was not isolated from either of these atypical barley sites, but always occurred in wheat, except that from the Residual Phosphate experiment, and was most common where grass preceded wheat. The inverse correlation of PRG and GGT was most dramatically illustrated by the difference between isolations from two replicate crops of the second wheat after lucerne in the Survival of take-all experiment, only the means of which are shown in Table 11; one replicate had 90% roots with GGT, 20% with PRG, and the other had 8 and 41% respectively. These differences may have been caused by an observed accidental contamination with some grass seed, known to have occurred on the latter replicate when the lucerne was sown in 1971. If so, the practical implications may be important.

TABLE 11

Prevalence of Gaeumannomyces and Phialophora on wheat and barley

		Sample for isolations			Sample for microscopic examination		
Group 1	P manuring (kg P/ha)	Take-all lesions (% root pieces)	GGT (% root pieces)	PRG (% root pieces)	Take-all lesions (% root pieces)	Vascular discoloration (% root pieces)	Vesicles PRG (% root pieces)
Broadbalk							
2nd wheat after fallow (?ND)	0	51	59	5	46	47	3
	35	13	13	8	10	12	12
8th successive wheat (D)	0	25	29	1	20	22	1
	35	30	29	2	18	24	6
PK and take-all experiment							
Wheat after 6 barleys (D)	0	36	43	2	28	48	1
	60	32	33	12	24	41	10
Residual Phosphate experiment							
Wheat after 1 barley (ND)	0	82	78	0	72	77	0
	50	2	2	0	2	13	0
Group 2							
Survival of take-all experiment							
1st wheat after 3 yr lucerne (ND)	16	0	0	12	0	1	11
2nd wheat after 2 yr lucerne (ND)	16	43	49	30	42	41	38
3rd wheat after 1 yr lucerne (?ND)	16	53	61	15	47	61	10
1st wheat after 3 yr grass-clover (ND)	16	0	0	56	0	2	78
2nd wheat after 2 yr grass-clover (ND)	16	16	14	31	13	15	42
3rd wheat after 1 yr grass-clover (ND)	16	59	65	8	48	54	11
Highfield Ley-arable experiment							
6th wheat after Lu sequence (D)	32	23	29	11	25	33	11
6th wheat after Lc sequence (D)	32	25	32	1	19	26	1
Group 3							
Barnfield				PRR			PRR
1st barley after potatoes (ND)	35	3	2	0	2	18	0
Hoosfield							
Continuous barley (D)	0	22	16	13	23	77	3
	35	1	0	6	0	17	2

(D) = take-all 'decline' established; (ND) = 'decline' not established.

https://doi.org/10.23637/ERADOC-1-131

On all wheat crops the assessments of vascular discoloration agreed well with take-all lesions and with isolations of GGT, but on barley there were marked discrepancies, particularly on Hoosfield barley without phosphate. This suggests that a cause other than GGT may account for some vascular discoloration in barley roots and perhaps explain our difficulties in diagnosing take-all on barley deficient in phosphate (*Rothamsted Report for 1971*, Part 1, 143–145). These results support the evidence that PRG is associated with slow increase of take-all after grass leys. They also suggest that neither PRG or PRR contributes to 'take-all decline' or to the effect of phosphate on take-all. (Slope, Salt, Broom, Etheridge, Gutteridge, and Rushforth)

Take-all fungi and associated viruses from other countries. Because of recent work on viruses and taxonomy, it is necessary to examine take-all fungi from different regions, climates, soils and agricultural conditions. Our reports (Rawlinson *et al.*, *Annals of Applied Biology* (1973) **74**, 197–209) of the incidence of viruses in the take-all fungus differed from those of workers in France. However, when we made isolations from take-all patches in a second wheat crop in Brittany they were morphologically indistinguishable from British *Gaeumannomyces graminis* var. *tritici* (GGT), caused moderately severe take-all on assay seedlings and perithecia (containing ascospores 80–90 μm long) developed from 11 of 15 isolates when the roots of assay plants were rotted in moist conditions under artificial light. Similar isolates (ascospores 77·9 $\times$ 3·9 μm) were obtained from take-all infected durum wheat at Foggia in Italy. (Hornby)

Of 22 GGT isolates from Brittany 21 contained virus particles 35 nm and 40 nm in diameter and seven also contained 27 nm particles. This is the first time the two larger particles have been reported in French material. Particles of the largest size have appeared only twice, in English PRR isolates, the two smaller sizes are common in English GGT. Mycelial extracts of virus infected French isolates reacted with an antiserum prepared against a mixture of the two smaller particles from English isolates. Ten French isolates, some with no particles, some with the two larger or all and varying in growth rate, pigmentation and perithecial production proved equally pathogenic to wheat seedlings.

These observations show similarities between GGT isolates in France and England and between the types and some serological properties of the virus particles they contain. It is likely that as more isolates are compared the differences reported between regions will further decrease. Because the isolates from Brittany came from the second wheat of a sequence where take-all was severe, they provide no support for the hypothesis that viruses cause take-all decline. (Rawlinson and Muthyalu)

Five cultures believed to have caused take-all in the American Middle-West differed morphologically from our GGT, did not contain virus particles and were not pathogenic to wheat seedlings at Rothamsted. Four cultures remain sterile and unidentified, the fifth has been identified as *Wojnowicia graminis*; a fungus that attracted attention in early studies of cereal root and foot rots and more recently may have caused a disease resembling take-all in Bulgaria (Todorova, V., *Bulletin of Plant Protection*, Sofia (1957), **6**, 15–28) and was associated with *G. graminis* in root rot complexes in European Russia. Further comparisons seem necessary to ensure that diseases caused by pathogens other than *G. graminis* var. *tritici* are not being called take-all or that associated fungi are not being mistaken for the causal fungus. (Hornby)

Five pathogenic isolates of GGT from wheat in Kenya, that produced numerous perithecia on agar contained 35 nm virus particles or 27 and 35 nm particles. The latter reacted against the antiserum to mixed particles mentioned above. (Rawlinson and Muthyalu)

Similar viruses in* Gaeumannomyces *spp and* Phialophora *spp. The possibility that our

https://doi.org/10.23637/ERADOC-1-131

PRR is the imperfect state of *G. graminis* var. *graminis* (p. 226) led us to examine isolates for viruses typical of other varieties of *G. graminis*.

When partially purified extracts of 30 isolates each of GGT and PRR from Hoosfield were examined, 20 of the former and 13 of the latter contained either one or both 27 and 35 nm diameter virus particles typical of GGT isolates from elsewhere (p. 228). Virus preparations from PRR reacted serologically with antiserum prepared against a mixture of the two particles common in GGT (p. 228).

Very few of the microconidia of PRR germinated in sterile distilled water, but one culture was grown from microconidia from a virus infected parent; it contained no particles.

The demonstration of affinities between the viruses of these fungi might help to explain their relationships or to clarify the epidemiology of virus infection in GGT. (Rawlinson and Muthyalu)

Survival of virus-infected isolates of* G. graminis *var.* tritici *in soil. Previous work (p. 228) indicated that viruses were not a main cause of take-all decline but did not exclude the possibility that they might assist it by shortening the survival of GGT in soil. Wheat straws were colonised with single ascospore isolates free from virus or by isolates with or without viruses from roots of second, third and sixth consecutive wheat crops. The straws were buried in April in adjacent plots on Little Knott Field growing first or fourteenth consecutive wheat crops. Each month 100 straws colonised by each isolate were removed, split to hold germinated wheat seeds and placed in moist grit for 21 days at 19°C. The growth of seedlings and the frequency and severity of take-all lesions they developed were used to assess the survival of inoculum.

No isolate was recovered from straws after September and survival depended more on the initial pathogenicity of an isolate than on the presence of viruses, which had no consistent effect. Nevertheless, it was interesting that all isolates survived better in soil carrying the first wheat crop than the fourteenth. (Rawlinson and Muthyalu)

Pythium *infection of cereal roots.* Of several *Pythium* spp. implicated in 'browning root rot', *P. arrhenomanes* was previously found most damaging (*Rothamsted Report for 1971*, Part 1, 146). Barley seedlings were transplanted into a sand-loam mixture (half autoclaved, half not) to which *P. arrhenomanes* was introduced in corn meal-sand inocula (control inocula autoclaved). Average disease ratings/root axis (Max. 3) were: Control inoculum, sterile soil 0·3; control, unsterile soil 0·7; inoculated, sterile soil 2·9 and inoculated, unsterile soil 1·4. The shoot dry weights were, respectively 934, 489, 102 and 372 mg. The effects of added nutrient and inoculation to sterile soil were dramatic but perhaps less important than the modest effect of inoculating unsterile soil.

Table 12 shows results of another experiment involving two amounts of P (supplied in half-strength Hoaglands solution, ± phosphate). *Pythium* infection decreased shoot

TABLE 12

Effect on barley of inoculation with Pythium arrhenomanes

		NPK			NK		
		Tops (dry wt. mg)	Roots (dry wt. mg)	Disease rating on roots (0–5)	Tops (dry wt. mg)	Roots (dry wt. mg)	Disease rating on roots (0–5)
Sterilised soil	Control	2310	989	0	1677	750	0
	Inoculated	962	124	4·00	309	65	4·38
Unsterilised soil	Control	924	237	0	322	120	1·50
	Inoculated	479	122	1·62	89	32	3·50

https://doi.org/10.23637/ERADOC-1-131

and root yield most where P was deficient. The disease ratings suggest that the difference resulted more probably from greater susceptibility of P-deficient roots than inability of a diseased root system to gain sufficient nutrients in P-deficient soils.

Parasites of Pythium. Roots of barley grown in Kettering loam inoculated with *P. arrhenomanes* and later placed in water, produced hyphae with unusual terminal or intercalary swellings. These proved not to be zoosporangia of an adventive *Pythium* sp. but malformations caused by parasitic lower fungi. A *Rozella* sp. (*Chytridiales, Olpidiaceae*) formed no resting spores, so identification was impossible. A member of the *Plasmodiophorales* produced zoosporangia like those of *Woronina* spp. of which *W. pythii* parasitizes *Pythium* but the cystosori most closely resembled *Sorosphaera*. (Macfarlane and Salt)

Disease in reduced cultivation systems. A direct drilling treatment was introduced to the Cultivations for Cereals experiment (R/CS/90) conducted at Rothamsted in conjunction with the National Institute of Agricultural Engineering and Plant Protection Ltd. The same collaborators planted an experiment (R/CS/135) where winter barley was grown after ploughing (20 cm deep), tine cultivation (15 cm) and direct drilling specifically to study the development of *Rhynchosporium* and other leaf diseases. We also undertook stratified soil sampling for the distribution of take-all inoculum (Hornby and Henden) and disease surveys on collaborative experiments with NIAE and ADAS at Silsoe and Boxworth Experimental Husbandry Farm and with the ARC Letcombe Laboratory and the Weed Research Organisation.

TABLE 13

Effect of cultivations on diseases and yields of winter cereals

Treatment	% straws with Eyespot	% straws with *Fusarium* foot rot	% Plants with Take-all	Yield (t/ha)
Winter barley: Rothamsted				
Ploughed	33 (17)*	2	86 (15)*	5·05
Tine cultivated	71 (36)	9	82 (25)	5·36
Direct drilled	49 (27)	6	90 (48)	4·33
Winter wheat: Rothamsted				
Ploughed	70 (33)	10	71 (16)	5·61
Tine cultivated	67 (25)	26	62 (14)	5·41
Direct drilled	58 (22)	17	58 (10)	5·13
Winter wheat: Boxworth EHF				
Ploughed	74 (57)	30	21 (0)	7·46
Tine cultivated	85 (68)	29	30 (1)	6·60
Direct drilled	64 (51)	31	17 (1)	6·92

* ( ) moderate and severe symptoms.

Table 13 records foot and root rot diseases on treatments common to three experiments. Mildew and *Septoria* diseases are not reported because the small amounts did not differ with treatments. By December the winter barley had become differentially infected with *Rhynchosporium secalis* (% area infected of 2nd leaf down) ploughed 0·8, tine cultivated 6·2, direct drilled 7·4; by mid-February this had increased (% area 4th leaf) to, respectively, 7·0, 7·2, 18·6. However, growth and dry weather later equalised incidence so that by June, third leaves of all treatments had only 2–3% area infected. *Fusarium* ear blight appeared on a Letcombe Laboratory spring wheat experiment. Infection was greater on direct drilled plots, 26% of ears, than on tine-cultivated 12%, or ploughed 10%. (Prew)

https://doi.org/10.23637/ERADOC-1-131

Diseases of grass and forage crops

Ryegrass mosaic virus (RMV)

***The vector* (Abacarus hystrix).** To assess when mites were dispersed, plots were sown with S 22 Italian ryegrass in October 1973 and each month from April to October 1974. No *A. hystrix* was found until mid-June but by mid-November mites had colonised plants in all plots sown before September. The indication that mites disperse between June and September confirms the conclusion from exposing potted plants during 1973 (*Rothamsted Report for 1973*, Part 1, 136).

The frequency, method and extent of grass removal influence the mite populations of swards. Plots of spring-sown S 22 Italian ryegrass were cut on 27 August at 3 or 13 cm above ground and the crop removed at once or after three days, to simulate respectively, silage or hay making. The extreme contrast by 24 October was between 46 mites/tiller on plots from which grass cut at 3 cm was removed at once, and 693 mites tiller where grass cut at 13 cm lay for three days. The latter plots also had nearly twice as many tillers showing ryegrass mosaic.

Glasshouse experiments have shown that infection with RMV greatly decreases the multiplication of mites on S 22. Three weeks after infesting each plant with 20 mites, plants mechanically inoculated with RMV averaged five mites each, compared with 114 mites on healthy plants. Similar limited multiplication on infected plants has been noted in caged cultures and may be an important factor in the epidemiology of RMV. (Gibson)

Mechanical transmission of RMV and its effect on yield. In Experiment R/CS/122 (*Rothamsted Report for 1973*, Part 1, 136) where ryegrass is grown under a polyethylene film-house to exclude mite vectors, 0, 25, 35 and 43% of tillers had been infected by manual inoculation in September 1973. Despite cutting plots four or eight times and also rolling some, the average infection in August 1974 was only 2, 39, 32 and 35%. Plots were cut and rolled in sequences designed to minimize or maximize transmission. Virus was transferred only to healthy plots which were both cut and rolled immediately after rolling an infected plot. Rolling seemed not only to transfer virus from plot to plot but from plant to plant within a plot. Infection increased from 20 to 28% of tillers in plots cut four times but, surprisingly, decreased to 16% in plots cut eight times. No mites were found within the film-house so transmissions cannot be attributed to vectors and the transmission of RMV by cutting and rolling was less than often observed in fields, suggesting that mites are the most important means of spreading RMV.

Although the plots with most RMV yielded 10% less than uninfected plots, the difference was not significant and unexpectedly small. The small difference is unexplained, but could result from using a mild isolate of RMV or, from the warmer, humid conditions in the film-house ameliorating the effects of the virus or from increased compensatory growth of healthy plants. (Gibson and Plumb)

Incidence on ryegrass varieties. Three varieties of Italian and six of perennial ryegrass were grown to compare the incidence of pathogens (Experiment R/CS/107). Among foliage fungi only *Helminthosporium* spp. were frequent. All varieties showed ryegrass mosaic, the average infection was greater on Italian (47%) than perennial varieties (29%). The least infected Italian variety was S 22 (29%) and among perennials Endura (6%) and S 24 (18%). Mite vectors averaged 10/tiller on all varieties from June to September but in October there were most on Reveille (a feeding preference apparently shared by hares during the winter).

In the glasshouse it proved easier to inoculate the same Italian varieties (80–90% plants infected) than perennials (50–70%) and varieties had the same susceptibility

https://doi.org/10.23637/ERADOC-1-131

rankings as in the field. This suggests that susceptibility to RMV depends on host metabolism more than mode of infection, because most natural spread is thought to be by mite vectors (see p. 231) (Plumb, Jenkyn and Bowen).

A possible relation between RMV incidence and age of ryegrass swards. Swards of S 23 perennial ryegrass at the Grassland Research Institute, Hurley, ranging from 1–20 years from sowing, were examined to see if there was any relationship between age of sward and RMV prevalence. Most RMV (24% infected tillers) occurred in a sward five years old and average infection was no greater in three old swards (15–20 years, 6% RMV) than in three that were only two years old. From this limited survey RMV incidence appears to rise to a maximum within a few years and then decrease. We confirmed the field assessments of symptoms by inoculating S 22 Italian ryegrass plants with sap from field plants and examining it for RMV particles in the electron microscope. Evidence suggests that many plants from old ryegrass swards may be difficult to infect, because only a third of healthy plants taken from swards became infected after having been inoculated manually three times with infective sap and abrasive. (Gibson and A. J. Heard, Grassland Research Institute, Hurley)

Effects of BYDV on ryegrass. Another film-house was used to exclude aphid vectors and maintain controls free from BYDV. Because BYDV can be transmitted only by aphids, plots had to be infected by caged aphids which were later killed. Plots of S 22 Italian ryegrass and S 24 perennial ryegrass were each infested with *Rhopalosiphum padi* or *Macrosiphum* (*Sitobion*) *avenae* each carrying a different isolate of BYDV. After two cuts infestation with *R. padi* has had no effect (perhaps because the aphids did not survive long enough to transmit virus), nor has the yield of S 24 been affected. However, yields of S 22 infested with *M.* (*S.*) *avenae* were decreased by 15 and 5% when cut in August and September. (Plumb)

Chemical control of ryegrass pathogens

Effect of aldicarb on a mixed sward. During the second year of Experiment R/CS/123, applying aldicarb (10 kg a.i./ha) to RvP Italian ryegrass after each of three cuts continued to decrease the prevalence of *A. hystrix* and RMV (from 54% untreated to 12%). Untreated mixed swards of ryegrass and broad red clover (Hungaropoly) had less RMV, 25%, which aldicarb decreased to 3%. Plots that had been inoculated with RMV in spring 1973 were still more infected than uninoculated plots but the difference was insufficient to affect yield.

Aldicarb increased total yield (three cuts) of RvP by 23% ($P = 0{\cdot}01$), and of pure clover by 16% ($P = 0{\cdot}01$) but did not affect mixed swards. As this chemical affects many organisms it would be unwise to attribute all the increased yield of ryegrass to decreased RMV. However, ryegrass contributed more to the yield of mixed swards that were treated with aldicarb than to swards that were untreated but inoculated with RMV. (Plumb, Cockbain and Bowen)

Effects of an acaricide and an aphicide on RMV, mites and yield. Experiment R/CS/106 was begun in 1972 to test whether pathogens of perennial ryegrass could be controlled with chemicals (*Rothamsted Report for 1973*, Part 1, 114, 138). Repeated endosulfan spraying decreased the prevalence of RMV and of *A. hystrix*; it also gave the best yields at two cuts although the increase was only significant (10%, $P = 0{\cdot}01$) at the first cut (Table 14). Menazon alone did not increase yield. Plots given least nitrogen had by far the most mites (28 October) and slightly less RMV when unsprayed, but when sprayed

https://doi.org/10.23637/ERADOC-1-131

with endosulfan they showed the greatest proportional yield response. (Plumb and Bowen)

TABLE 14

Effects of an acaricide, an aphicide and nitrogen fertiliser on RMV, its vector and ryegrass yield

	kg N/ha/cut			
	38	75	150	
Treatment	Yield (Total of 2 cuts) DM (t/ha)			
—	7·68	11·32	12·91	SED 0·51
EN	8·97	12·48	14·05	
	Mites/5 tillers (28 October)			
—	226	19	1	
EN	23	6	0	
	% tillers infected (April)			
	RMV			Mean
—	50·7	53·3	60·0	56·4
EN	12·0	29·3	34·7	24·6
ME	40·0	34·7	56·0	43·5
EN+ME	16·0	28·0	32·0	25·0
Mean	29·9	35·7	45·7	

—=No treatment.
EN=Sprayed with acarcide (endosulfan).
ME=Sprayed with aphicide (menazon).

Residues of endosulfan. Chemicals were used liberally in Experiment R/CS/106 rather than to obtain an economic return. However, the success of endosulfan was sufficient to encourage further work to test whether it could be safely and profitably used. Four weeks after the final spraying in August, total residues of endosulfan and its sulphate metabolite of 0·01–1·35 ppm fresh wt. were measured in grass leaves by gas chromatography. Ten weeks after spraying, root samples still contained large endosulfan residues (0·93–1·45 ppm fresh wt) but soil contained much less (0·04–0·08 ppm dry wt.) The results suggest that in roots there is a direct relationship between endosulfan residues and nitrogen applied but an inverse relationship in leaf and soil. (Austin and Rolfe)

The incidence of fungal diseases in ryegrass. Although *Helminthosporium* spp. caused widespread leaf spotting in Experiment R/CS/106, there was no evidence of serious damage by foliage or soil-borne fungi and none of the fungicides affected yield. Nevertheless, in August, patches of grass appeared dead or slow to recover after the second cut on plots given most N (where the gaps were estimated to occupy over a tenth of the area). No fungus could be associated with the patches and no symptom was seen in wheat and ryegrass seedlings grown in soil samples from bare patches and beneath healthy ryegrass. However, the seedlings grown in soil from patches where ryegrass grew poorly weighed 25% more than the others, possibly because applied N had not been used in the patches. *Agropyron repens* was common throughout the experiment and its growth was not inhibited in the poor patches. It was most prevalent where most N was given even before patches appeared. (Broom and Jenkyn)

Fusarium spp. have sometimes been associated with dead grass from areas given much nitrogen. On several occasions *F. culmorum* was isolated from many dead roots but from few, if any, that were little discoloured. One isolate was tested for pathogenicity to wheat and rygrass seedlings by inoculating sterilised or unsterilised loam. All wheat seedlings

https://doi.org/10.23637/ERADOC-1-131

were killed in inoculated sterile soil and even in unsterile soil inoculation produced much browning of their roots and coleoptiles. Inoculation reduced the emergence of ryegrass seedlings only in sterile soil but caused no symptom in unsterile soil. Under the test conditions this isolate of *F. culmorum* seems not to have been an aggressive primary pathogen of ryegrass. (Broom)

Effect of benomyl on clover rot (*Sclerotinia trifoliorum*). Last year, the first when clover was treated with benomyl in autumn and winter (*Rothamsted Report for 1973*, Part 1, 138–139), yields were increased 32% with monthly sprays from September to January. As Table 15 shows, repeating the treatments on the same plots in 1973–74 gave very different results. Yield was increased (15%) only on plots sprayed five times with benomyl all other treatments yielded less than untreated. The results might be explained if a few benomyl sprays removed an antagonist, whereas only repeated sprays killed *S. trifoliorum*. So far, there is no evidence to confirm this. (Jenkyn)

TABLE 15

The effect of fungicide sprays on yield of red clover

Fungicide	Dry matter yield 5 July 1974 (t/ha)
None	3·47
benomyl September & October	1·92
benomyl October & November	2·08
benomyl November & December	2·89
benomyl September–January	3·99

SED for comparisons between fungicide treatments and untreated=0·267.

Soil samples taken from plots that received 0, 2 or 5 sprays each autumn contained, on average, respectively none, 0·08 and 0·33 ppm of carbendazim, the fungitoxic degradation product of benomyl. However, the recovery from individual treated plots again varied with soil pH (*Rothamsted Report for 1973*, Part 1, 147). (Austin)

Crown wart of lucerne (*Urophlytcis alfalfae*) at Saxmundham. During June this unusual fungus was noticed in the Rotation Experiment at Saxmundham and seemed to have caused a few patches of thin crop. Early in July crown wart was present in every plot and in some plots 75% of plants had obvious galls. By September the galls were marbled brown inside, as resting spores formed and some were distintegrating.

The life cycle of *U. alfalfae* is incompletely known but probably involves two zoosporic stages requiring water around the crowns. The size of galls suggested winter infection and there was 88 mm of rain in January–February, but only 48 mm during the next three months. The source of infection is unknown because neither the field nor its neighbours had previously grown lucerne for many years. (Macfarlane)

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

Incidence of virus diseases during 1974. Unlike sugar beet and potatoes, where aphids caused exceptional spread of viruses, fewer than 10% of bean plants in most crops at Rothamsted were infected with any one of the aphid transmitted viruses. The main weevil vector (*Apion vorax*) of broad bean stain virus (BBSV) and Echtes Ackerbohnenmosaik-Virus (EAMV, syn. broad bean true mosaic virus) was also less prevalent than in 1973. Nevertheless it was sufficiently numerous to infect up to 70% of plants in plots with 3% seed-borne infection. By contrast both viruses remained very rare in crops grown from virus-free seed. The importance of healthy seed even showed through the

https://doi.org/10.23637/ERADOC-1-131 *pp 25*

interference between plots in an experiment (74/R/BE/3) where stocks with widely different amounts of seed infection were sown adjacent to one another (Table 16). Few plants developed symptoms (BBSV/EAMV) until flowering was almost over and then serological tests showed that EAMV was the more common. The variety Minden out-yielded its nearest competitor Minor by 26%, and Herz Freya by 53%. However, the two stocks of Maris Bead apparently yielded similarly despite their very different appearance and virus infection. Perhaps significantly, plants of Maris Bead Stock II that showed symptoms of BBSV/EAMV at the end of flowering did not yield significantly less than plants without symptoms (Stock I was not similarly tested), whereas in Minor, Herz Freya and Minden, respectively, plants with BBSV/EAMV in mid-July yielded 28, 29 and 42% less than symptomless plants.

TABLE 16

Virus incidence and yields (85% DM) of different field bean cultivars

	BBSV/EAMV		BLRV	BYMV/PMV and PEMV	Yield
	(% seed infected)	(% plants infected July)	(% Plants infected July)		(t/ha)
Cultivar					
Herz Freya	0·02	29	17	6	3·03
Maris Bead I	3·2	68	7	5	3·32
Maris Bead II	0·04	27	5	4	3·14
Minden	0	13	16	4	4·64
Minor	0	16	2	8	3·68
SE of differences					±0·274* ±0·316**

* Maris Bead I v. any of remainder.
** Between any of remainder.

Large differences in BBSV/EAMV incidence (0·1–66%) also occurred in July between eight crops in Hertfordshire, Middlesex and Essex surveyed in collaboration with the Agricultural Development and Advisory Service. Some crops showed much more of the aphid transmitted bean yellow mosaic/pea mosaic virus (5–80%) than crops at Rothamsted but bean leaf roll virus (2–13%) and pea enation mosaic virus (0·6–4%) were not dissimilar.

Attempts to control the spread of BBSV/EAMV

Unsuccessfully, by treating seeds. Previous tests had suggested it worthwhile to test heat treatment at 80°C for 1 h. In one stock this decreased infection from 7·3 to 0·8% but in another did not decrease infection and decreased emergence in the field by 45%.

Seeds were allowed to imbibe (24 h) solutions of several substances that have shown inhibition of viruses. Polyacrylic acid solutions (mol. wt. 1700 and 3500) or 0·01% 8-azaguanine did not decrease seed infection, 0·01% 2-thiouracil damaged or killed the seeds. (Cockbain and Bowen)

By insecticides, against weevil vectors. Phorate granules (applied three times at 1·0 kg a.i./ha) seemed less effective than sprays of fenitrothion (3 × 0·75 kg), malathion and methomyl (both 3 × 1·0 kg) in checking the spread of BBSV/EAMV in plots of Maris Bead containing 3% seed-borne infection (Experiment 74/R/BE/6). Early in July an average of 14% of plants were infected with BBSV/EAMV in sprayed plots, 19% in plots with granules and 35% in untreated plots; corresponding data at the end of flowering (mid-July) were 35, 41 and 61% (all plots were sprayed twice with demeton-S-methyl ('Metasystox') to prevent aphids damaging 'untreated' plots). This experiment, like many other bean experiments in 1974, was damaged by wind and rain, and much

https://doi.org/10.23637/ERADOC-1-131 *pp 26*

seed was lost from some treated plots. Only malathion (4·41 t/ha) and phorate (4·42 t/ha) significantly increased yield above untreated (3·55 t/ha) ($P = 0·05$). (Cockbain and Bowen, with Etheridge, Insecticides and Fungicides Department)

Freedom of pea crops from BBSV and EAMV. Peas (cv Dark Skin Perfection and Maro) were grown adjacent to field beans (Maris Bead, 3% seed infected) to test whether they became infected. By mid-July 52% of the beans, but none of the peas, showed BBSV/EAMV symptoms. Serological tests on 160 plants of each pea cultivar revealed only one infected plant (D.S. Perfection with EAMV). Pea growers should be much relieved by this result, because glasshouse tests show that peas are very susceptible to both viruses when inoculated mechanically. Their freedom in the field probably reflects the poor efficiency, as a vector, of *Sitona lineatus*, which was common on both pea and bean seedlings, and the unattractiveness of peas to *Apion* spp. In June only one *A. vorax* and one *A. apricans* were found on 200 m of pea rows, compared to 72 *A. vorax* on 100 m of field bean rows.

Attempts to transmit BBSV and EAMV by aphids. Early tests indicated that aphids could not transmit these viruses but a Polish claim that EAMV is transmitted by *Aphis fabae* (Blaszczak & Kurhanska, Zeszyty Problemowe Postepow Nauk Rolniczych (1971) **115**, 145–148) made re-examination necessary. Nymph and adult *A. fabae* (400 tested) or *Acyrthosiphon pisum* (300) failed to transmit after feeding on infected plants for 0·25–2 min or for four days. Comparable tests with BBSV also failed. (Cockbain and Bowen)

Biology and ecology of *A. vorax*. Until it was recognised as the main vector of BBSV and EAMV, *A. vorax* was not regarded as an agricultural pest. Knowledge of its biology and ecology came mostly from naturalists who knew it chiefly as a woodland species, widespread except in extreme western areas and Scotland north of the Lothians.

Recent observations confirm that adult weevils commonly overwinter in woods. In April and May 1974 we found them on *Crataegus monogyna* (hawthorn), *Mercurialis perennis* (dog's mercury), *Prunus avium* (wild cherry), *Rubus* spp. (bramble) and *Urtica dioica* (nettle). Migration to beans commenced early in May so that in June and July there were up to 12/10 m of field bean row and only a few males remained in woodland. Early in July larvae and pupae were found in field bean flowers (83 in 3800 flowers) and began emerging as adults late in the month. By late August most *A. vorax* had migrated back to hedgerows and woods where they aggregated particularly on *Acer pseudoplatanus* (sycamore), *Corylus avellana* (hazel), *P. avium*, *Rubus* spp. and *Sambucus nigra* (elder). The ecology and geographical distribution of *A. vorax* merit further study because it may be rare in some localities or where there are few hedges or woods. Such areas may be suitable for producing virus-free bean seed. (Cockbain, Bowen and Bartlett)

Other pests and diseases. Residual effects of chemicals applied cumulatively for crops on Barnfield during 1971, 1972 and 1973 were measured in the eighth consecutive crop of spring beans cv. Maris Bead. Table 17 shows that the residual effects of aldicarb, fenaminosulf ('Dexon'), and a mixture containing these, noticeably increased growth and yield in 1974; aldicarb also delayed senescence. The effects are not understood, although root systems were uniformly blackened by the end of July they were not extensively rotted, similarly wilting appeared late in June but never became serious. Plots that received aldicarb alone, or with fenaminosulf and formaldehyde had respectively 62% and 67% stems infested with stem eelworm, *Ditylenchus dipsaci*. This was much more than the 3 and 4% recorded after treatment in 1973, but probably still less than other treatments that had over 90% infested in 1973 but which were too discoloured for a

https://doi.org/10.23637/ERADOC-1-131

reliable count in September 1974. (Salt and Hornby, with D. Hooper, Nematology Department)

TABLE 17

Residual effect of chemicals on growth, yield and wilt of field beans. Barnfield 1974

Treatments	Yield (t/ha)	Height cm	Plants wilted 17 July (%)
Nil	2·54	104	8·2
fenaminosulf (F)	3·20	111	7·3
aldicarb (N)	3·40	113	6·4
BHC (I)	2·92	111	9·4
formaldehyde (B)	2·54	108	12·5
F+N+B	3·59	119	3·8
SED (n=4)	±0·348		

Diseases of brassica crops

Oilseed rape (*Brassica napus* var. *oleifera*). The area of this crop has increased greatly in recent years; such expansion often outpaces the full establishment of pests and diseases. The interval provides an opportunity for research on potential problems. Crops were surveyed in Hertfordshire, Bedfordshire and Northamptonshire.

At Rothamsted, *Perenospora parasitica* caused local lesions only on the lower leaves of many plants sown in autumn 1973 and 1974. Powdery mildew (*Erysiphe cruciferarum*) became abundant in late summer on a spring-sown crop. Elsewhere, *Botrytis cinerea* lesions girdled and withered the centre branches of infloresences on isolated plants. (Macfarlane)

Many plants on the edges of two crops (cv. Victor) in Hertfordshire were infested with the cabbage aphid (*Brevicoryne brassicae*) and became stunted, apparently as a result of infection with turnip mosaic virus. Both were near kale crops affected by the same virus. Glasshouse inoculation of six varieties of winter oilseed rape showed that all were stunted with reduced leaf area. Plants of the spring variety Erglu were inoculated at stages from the first true leaf to the formation of flower buds. Plants with up to nine leaves when inoculated never became so tall and developed fewer, smaller pods containing fewer seeds. (Rawlinson and Muthyalu)

Effect of fungicides on the yield of swedes. Plots without fungicide yielded 40·3 t/ha of trimmed swedes, whereas those sprayed three times with benomyl yielded 67·0 t/ha. Diseases other than powdery mildew may be concerned because tridemorph produced a smaller yield (55·0 t/ha) although it controlled mildew as well as benomyl. Applications and other treatments are detailed in *Yields of the Field Experiments, 1974* (Experiment 74/R/SW/1). (Jenkyn)

Potato diseases

Our experiments met many difficulties during 1974. Excessive sprouting occurred because the new store was insufficiently insulated and the winter exceptionally mild. Wet soil in winter delayed planting and emergence but then drier cool weather retarded growth. Fortunately rain in June came just in time to rescue the crop but after August continued increasingly, so that lifting did not begin until mid-October and discard rows remained in the ground at Christmas. Nevertheless some potato yields were exceptionally large. The delay in estimating yields and analysing disease incidence on the produce prevents inclusion of many results in this report, therefore aspects of our work on storage and the survival of pathogens are emphasised.

https://doi.org/10.23637/ERADOC-1-131

Activity of soft-rotting *Erwinia* spp. in soil. Warm dry soils limit and cool wet soils favour both increase and survival of *Erwinia carotovora* var. *atroseptica* and *E.c.* var. *carotovora*. Open-ended tubes 15 cm long, filled with soil infested with either variety were sunk vertically to soil level on 16 January, 4 June, 4 July and 12 September. After 6 wk burial, populations had decreased from an initial 10^{10} cells/g soil to, respectively, about 10^4, 10^2, 10^2 and 10^3 cells/g soil. Soil buried in January and July still contained live bacteria 20 and 10 weeks later and survival of the two varieties was similar.

Irrigated and unirrigated areas, both planted with King Edward and Pentland Crown were used to study how bacterial spread was affected by soil moisture. Seed tuber sources inoculated with an *E.c.* var. *atroseptica* strain identifiable by particular bacteriophage specificity or *E.c.* var. *carotovora* were planted among uninoculated 'detector' plants. In June, before progeny tubers were large, roots and rhizosphere soil were sampled; *Erwinia* spp. were found on 'source' plants on 5 June, on adjacent plants within the same row on 18 June and two plants along by 21 June. Spread was more often detected along rows on the irrigated than the unirrigated areas but never to adjacent healthy rows in July, August or September, when tuber lenticels were sampled.

By early November tuber samples dug by hand showed that the identifiable strain of *E.c.* var. *atroseptica* had reached the *E.c.* var. *carotovora* area and vice versa. At lifting (7 November) many tubers in the irrigated area showed soft rot, evidence that the bacterium had spread extensively during the very wet autumn.

Work elsewhere suggests that spread occurs mostly in July and August as seed tubers rot. Seed tubers were lifted from growing Maris Piper plants in mid-July, inoculated with either variety of *E. carotovora* and replanted close to the seed tuber of a King Edward 'receptor' plant. Soil and lenticel samples indicated that in late-July *E.c.* var. *atroseptica* had spread but not *E.c.* var. *carotovora*; populations then decreased until October when *Erwinia* spp. could not be found in progeny tubers even of original receptor plants.

In previous years we have reported failure to prove the Dutch theory that machinery is important in transmitting *E.c.* var. *atroseptica*. We thought the weather and soil was often too dry to express infections, so in 1974, we again planted samples of tubers lifted in 1973 from a healthy plot with a digger contaminated by passing through a plot infested with a strain identifiable by bacteriophage specificity. Some of these tubers were planted in soil-filled polyethylene bags so that the young plants could be waterlogged to exaggerate the expression of even minute bacterial contamination as blackleg symptoms or seed tuber rot. Some plants in bags and one in the field developed blackleg, but the test remained inconclusive because the identifiable strain was only recovered from the progeny tubers of the infested plot. Bacterial rots were induced in some tubers dug in mid-October but the labelled strain was only identifiable from plots where it had been introduced.

Assessing the bacterial contamination of tubers. We have now standardised the bucket test (*Rothamsted Report for 1973*, Part 1, 142) and estimated how gas concentrations are associated with the development of rots and changes in numbers of bacteria in lenticels. Quickly flushing the 10-litre buckets with approximately 22 litres of nitrogen decreased oxygen to about 1% but within 3d at 20°C it had increased to 7% despite the tight-fitting lids. Oxygen concentration then decreased again to c. 4% at 7d probably as a result of respiration by rapidly increasing bacterial populations that caused the first visible rotting on the third day. (Lapwood, Legg and Austin)

Potato and red beet common scab (*Streptomyces* spp.). The way in which irrigation hinders the development of common scab was studied by relating the microflora to the development of lenticels on tubers in wet or dry soils where the organism was prevalent

https://doi.org/10.23637/ERADOC-1-131

or scarce. The susceptible variety Maris Piper and the more resistant Pentland Crown differed in rate of lenticel development on progressively older tuber internodes and this differed also between years and soils but apparently not with soil moisture. Usually lenticels seemed not to become susceptible until the stomatal guard cells were lost, on about the third internode back from the apex. Isolating from lenticel areas produced more actinomycetes on distilled water agar from Maris Piper than Pentland Crown and more from tubers grown at Rothamsted than Woburn. Neither internode position nor soil moisture seemed to affect actinomycetes but tubers from wet soils yielded rather more bacteria. (Lapwood and Adams)

A similar (or identical) actinomycete causes scabs on red beet, that are especially troublesome if the crop is to be used for canning. We were disappointed that we could not control this, like common scab of potatoes, by irrigating and have been seeking an explanation. We know neither where the pathogen penetrates (although near the bottom of the root, infection is often associated with the insertion of fine lateral roots) nor when, except that transplanting experiments suggest that it may be at the six-leaf stage or later. The variety Boltardy was more susceptible than Avon Early, Bikor or the long-rooted varieties Cheltenham Green Top and Red Perfection. (Lapwood and Adams, with Agricultural Development and Advisory Service, Cambridge)

Gangrene (*Phoma exigua foveata*)

Detecting the pathogen in plants and soil. Inability to detect latent infections and slow development of lesions from wounds seriously hinder diagnosis and research. Our tests suggest it would be difficult to develop fluorescent antibody techniques into a practical test for locating the fungus in stems or tubers without lesions. Although the fungus grows distinctively on media containing various fungicides, none was suitable for enumerating *Phoma* propagules in infested soil. We have previously accelerated the development of lesions by suppressing wound healing and now find that they also grow faster if oxygen is decreased below 5% and temperature kept at 10–15°C instead of 5°C. (Adams)

Increase and survival of the pathogen in soil. Pentland Crown tubers with or without gangrene lesions were selected from a single stock, planted and their produce sampled nine times between July and September 1973. Tubers sampled were wounded, stored at 5°C and later examined for lesions; soil adhering to them was collected and inoculated to slices of Arran Banner test tubers. As previously, infectivity increased erratically between July and September and both tests indicated more *Phoma* from lesion-bearing seed. About 15% of 'lesion-free' seed tubers developed gangrene lesions after planting; by September, progeny tubers from seed planted with or without lesions developed gangrene equally after wounding.

Survival in sterile and non-sterile soil was tested by infesting each with spore suspensions, retaining at various moisture contents and, after 10 weeks, testing infectivity on Arran Banner tuber slices. Non-sterile soils at field capacity retained least infectivity. Much infectivity survived in soils that were kept dry or sterilised. Therefore soil dust in potato stores should be regarded as potentially infective if introduced into tuber wounds. (Griffith)

Control of infection on progeny tubers. In commercial production, raisers of VTSC potato stocks have not evaded early recolonisation of seed by *Phoma* and other pathogens. Their misfortune was not unexpected and fungicides to prevent reinfection have been tested for several years. Unfortunately, neither benomyl or thiabendazole dust on seed

https://doi.org/10.23637/ERADOC-1-131

tubers, nor fumigating with 2-aminobutane prevented infectivity increasing in and around the resulting plants.

Even stem-cuttings raised in the glasshouse from healthy looking tubers and grown out of doors in sterile soil, developed *Phoma* lesions on stems and some tubers. Therefore, either the pathogen is dispersed more readily than previously appreciated or it is much more difficult to propagate stem cuttings free from *Phoma exigua* var. *foveata* than from *Oospora pustulans* for which the technique was developed. (Griffith and Adams)

The adsorption and movement of benzimidazole fungicides in tubers and soil. Assays of thiabendazole (TBZ) adsorbed on King Edward and Pentland Crown tubers from solutions of various concentration (pH 3) showed from 30 to 70% less uptake than reported previously (Tisdale & Lord, Pesticide Science (1973), **4**, 121). Over the range of concentrations, tubers only adsorbed about 2% of the amount (ppm) present in the solution. No thiabendazole was detected in soils where dipped tubers were planted but seed tubers of Pentland Crown took up 37% more and retained after growth 67% more thiabendazole than those of King Edward. Pentland Crown tubers also seemed to acquire increased concentrations of thiabendazole the more mature they were when tested. Several solvents were tested for extracting thiabendazole from treated tubers but, as for benomyl residues (carbendazim (MBC) (*Rothamsted Report for 1973*, Part I, 147), the best was acetone: M ammonium chloride (1 : 1, v/v, pH 7).

The movement and persistence of carbendazim (from several precursors) was studied in soil. Neither [2¹-^{14}C]-2-(3-methoxycarbonyl-thioureido)-aniline ('NF 48') nor thiophanate methyl) showed significant downward leaching during seven months field exposure although both were quickly converted to carbendazim. The acetone: M ammonium chloride extractant was used to estimate carbendazim residues on Broadmead Field at Woburn. Twenty-eight and 38 months after 17·8 kg a.i./ha of benomyl was applied, replicate plots retained respectively, 19–49% and 8–29% of the amounts applied. The plots were limed one month after the first sampling and results show the amount of carbendazim recoverable is inversely related to the soil pH as is the half life of the residues, approximately 11 months in soil at pH 6·8 and 26 months at pH 5·4. In more alkaline soils at Rothamsted, benomyl residues were much less persistent and, at pH 7·2, half of the initial dose was lost in less than three months. Results from several separate field experiments with benomyl show that both soil pH (H_2O) and soil organic matter percentage (o.m.) affect persistence and can be related to DT_{50}, the time required for loss of half the initial dose, by the equation:

$$\log DT_{50} = 2{\cdot}94 - 0{\cdot}36\ \text{pH} + 0{\cdot}09\ \text{o.m.}$$

(Austin and Briggs, Chemical Liaison Unit)

Tuber maturity, wound healing and susceptibility to pathogens. These factors, so important during storage, were investigated with the Potato Marketing Board Experimental Station at Sutton Bridge, Lincs. King Edward tubers lifted at two-week intervals between mid-September and mid-November 1973 were uniformly wounded and stored at 15°C. After 0, 7, 14 and 21 days samples were examined microscopically and inoculated with standard suspensions of *E.c.* var. *atroseptica* or *Phoma exigua* var. *foveata* and stored at 20 and 5°C respectively. Date of lifting did not seem to influence the histological features of wound healing or bacterial infection but fewer wounds became infected the longer the curing period. Inoculation with *Phoma exigua* var. *foveata* never caused gangrene lesions on wounds on tubers that had been cured but fewer uncured tubers became infected the later they were lifted although their lesions were progressively larger. (Griffith, Legg and Adams)

https://doi.org/10.23637/ERADOC-1-131

Relationship between diseases of seed, plants and stored potato tubers. Observations were continued to test whether it is possible to identify crops potentially troublesome in store from examinations of seed tubers, growing plants or tubers at lifting. Crops that developed most gangrene and skin spot in store usually had above average potential disease in August but a large disease potential in growth did not necessarily imply much disease. It might be more reliable to attempt predicting which crops will store well because, where pathogens are scarce, serious disease is improbable whereas serious disease is not ensured wherever the pathogen is common. Even accurate assessment in August cannot predict the consequences of changed weather that may greatly alter disease potential, notably with bacterial diseases. For example, in July 1974 only four of 20 crops showed blackleg symptoms, compared to 15 in August. Similarly, an average of one colony of *Erwinia* spp. per lenticel was isolated from stocks on 8 September on loading into store but later in one stock there was a hundred times more in lenticels of apparently healthy tubers close to a developing spot of rot.

In 1973 the summer was dry and few tubers developed soft rot in store. Gangrene in store was more closely correlated with estimates of *Phoma* in soil in August ($r = 0{\cdot}70$) than at lifting ($r = 0{\cdot}45$), but almost the reverse was true of predicting silver scurf from the incidence of *Helminthosporium solani*, (August, $r = 0{\cdot}40$; at lifting $r = 0{\cdot}73$). Correlations were always closer when samples of the same seed stocks were grown together at Rothamsted and the range of variation was usually smaller. To measure differences between soils, the same stock originally raised from stem cuttings was grown on different farms. Infection varied considerably but usually if the progeny of commercial seed was relatively severely infected, so was the progeny of healthier seed. (Hide, Adams, Bell, Lapwood and Legg)

Potato virus diseases at Rothamsted. Experiments planted with seed grown in 1973 at Rothamsted contained more potato virus Y (1% in King Edward) than in any year since 1968, but no leaf roll. Neither virus was found in the resistant variety Pentland Crown. During 1973 *Myzus persicae* was not common and the amount of virus Y contracted by our 1973 seed was probably explained by unusually prevalent infection in surrounding crops, and an early aphid invasion, both associated with a succession of mild winters. These circumstances recurred in 1973–74 and potato virus Y spread rapidly in the experiments so that a large proportion of plants was infected by the end of the season.

The isolated crops grown to provide seed for 1975 did contain a few plants with leaf roll and severe mosaic. Spread of leaf roll was probably limited by systemic aphicides more than was spread of the non-persistent virus Y which caused leaf drop streak symptoms in 0·1% of plants by 23 July. If aphids are again common much infection could result in 1975. (Govier)

Top-roll of potato plants. This disorder, characterised by loose rolling of the upper leaflets, results from feeding by the aphid *Macrosiphum euphorbiae*. The widespread occurrence of top-roll in England during 1974 followed unusually large catches of *M. euphorbiae* early in summer (*Rothamsted Report for 1974*, Part 2, p. 201). The effectiveness of phorate granules in preventing the disorder was demonstrated dramatically in a field where two rows of Desiree potatoes accidentally escaped application. In these rows many upper leaflets were rolled and phorate was not detectable in soil, whereas there was no top-roll in treated rows and air-dried soil contained 6 ppm phorate in August.

The carbon dioxide absorption of top-rolled leaves was only half that of an equal area of unaffected leaves and leaf cover in the untreated, rolled rows was 20% less than in the treated rows; it seems therefore both decreased light interception and decreased photosynthesis contribute to the decreased yields where top-roll occurs. (*Rothamsted*

https://doi.org/10.23637/ERADOC-1-131

Report for 1972, Part 1, 218). (Gibson, Simkins and Austin, with D. Whitehead, Physics Department)

Survey of diseases of seed tubers. As in 1972–73 few tubers had blight. Gangrene affected 3% of King Edward and 5% of Pentland Crown tubers, but of sub-samples wounded and stored at 5°C, 20 and 17% developed the disease. Black scurf and powdery scab were of average incidence and common scab and skin spot below average. *Helminthosporium* (cause of silver scurf) was also below average and more infections were found on Pentland Crown than King Edward tubers. (Hide and Bell)

TABLE 18

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

Examined	Disease	King Edward	Pentland Crown
R	Skin spot (*Oospora pustulans*)	26/92	21/78
P	Gangrene (*Phoma exigua*)	3/48	5/46
P	Dry rot (*Fusarium solani*)	1/28	3/54
R	Blight (*Phytophthora infestans*)	<1/6	<1/8
R	Black scurf (*Rhizoctonia solani*)	27/98	34/100
R	Powdery scab (*Spongospora subterranea*)	18/74	2/36
R	Common scab (*Streptomyces scabies*)	19/96	9/90
	Number of stocks examined	50	50

R = examined at receipt.
P = chitted tubers examined at planting.

Staff and visiting workers

Those appointed to the research staff were Mrs. Roberta Bowen and Janet E. Smith. Brenda Hambling, Diane Moore, Jane Simkins, Noreen Sexton and Marilyn Kemp worked in the department as sandwich course students. R. L. Griffith resigned.

Visiting workers included Dr. T. G. Atkinson (Lethbridge, Canada), P. W. Bartlett, Professor T. Pirone (Lexington, USA), F. A. Powell (Melbourne, Australia) and S. Vorra-Urai who was awarded the Ph.D. Degree by London University and returned to the University of Cheingmai (Thailand). B. D. L. Fitt and R. A. Hill worked with Agricultural Research Council Scholarships and P. T. Gans joined the department with a postgraduate studentship provided by the Potato Marketing Board. Dr. P. H. Gregory continued working at the invitation of the Lawes Agricultural Trust Committee.

Three members of staff supported by the Ministry of Overseas Development worked abroad, R. H. Kenten at the Cocoa Research Institute, Ghana, S. J. Eden-Green on lethal yellowing of coconut in Jamaica and A. J. Dabek visited the British Solomon Islands Protectorate to continue the work on virus diseases of taro. The Agricultural Research Council supported visits by R. W. Gibson to laboratories in Canada and USA where mite transmission of plant viruses is studied, by D. Hornby and C. J. Rawlinson to France for discussions about diseases of wheat and maize and viruses infecting the take-all fungus and attendance by D. Hornby at a European Plant Pathology Discussion Group on 'Foot rots of cereals' at Kiel, Germany. In May, J. M. Hirst visited Stockholm and Uppsala at the invitation of the Swedish Aerobiology Group and J. Lacey later attended the 1st International Conference on the biology of Nocardiae at Merida, Venezuela.

We gratefully acknowledge financial assistance from the Potato Marketing Board and the Forestry Commission.

https://doi.org/10.23637/ERADOC-1-131 *pp 33*

Publications

Book

1 GREGORY, P. H. (Edit.) (1974) *Phytophthora disease of cocoa.* London: Longmans, *xii*, 348 pp.

Thesis

2 VORRA-URAI, S. (1974) Seed transmission and attempted control of broad bean stain and Echtes Ackerbohnenmosaik viruses in field beans (*Vicia faba* L.) Ph.D. Thesis, London University.

General Papers

3 LACEY, J. (1974) Allergy in mushroom workers. *Lancet i*, 366.

4 LACEY, J. (1974) The microbiology of hay and straw. In: *Aspergillosis and farmer's lung in man and animals.* Ed. R. de Haller & F. Suter. Bern, Stuttgart, Vienna: Hans Huber Publishers. pp. 16–26.

5 LACEY, J. (1974) Thermophilic actinomycetes associated with farmer's lung. In: *Aspergillosis and farmer's lung in man and animals.* Ed. R. de Haller & F. Suter. Bern, Stuttgart, Vienna: Hans Huber Publishers, pp. 155–168.

6 LAPWOOD, D. H. & ADAMS, M. J. (1974) Mechanisms of control of common scab by irrigation. In: *Biology and control of soil-borne plant pathogens.* Ed. G. W. Bruehl. The American Phytopathological Society.

Research Papers

7 ADAMS, M. J. (1975) Potato tuber lenticels: development and structure. *Annals of Applied Biology* **79**, 265–273.

8 ADAMS, M. J. (1975) Potato tuber lenticels: susceptibility to infection by *Erwinia carotovora* var. *atroseptica* and *Phytopthora infestans*. *Annals of Applied Biology* **79**, 275–282.

9 (AVILA, R.) & LACEY, J. (1974) The role of *Penicillium frequentans* in suberosis. *Clinical Allergy* **4**, 109–117.

10 BAINBRIDGE, A. (1974) Effects of nitrogen nutrition of the host on barley powdery mildew. *Plant Pathology* **23**, 160–161.

11 (BOCK, K. R., GUTHRIE, E. J.) & WOODS, R. D. (1974) Purification of maize streak virus and its relationship to viruses associated with streak diseases of sugar cane and *Panicum maximum*. *Annals of Applied Biology* **77**, 289–296.

12 BROWN, G., CORBETT, D. C. M., HIDE, G. A., & WEBB, R. M. (1974) Bromine residues in potato and wheat crops grown in soil fumigated with methylbromide. *Pesticide Science* **5**, 25–29.

13 BROWN, M. E., HORNBY, D. & PEARSON, V. (1973) Microbial populations and nitrogen in soil growing consecutive cereal crops infected with take-all. *Journal of Soil Science* **24**, 296–310.

14 GIANINAZZI, S. & KASSANIS, B. (1974) Virus resistance induced in plants by polyacrylic acid. *Journal of General Viorology* **23**, 1–9.

15 GIBSON, R. W. (1974) Studies on the feeding behaviour of the eriophyid mite *Abacarus hystrix*, a vector of grass viruses. *Annals of Applied Biology* **78**, 213–217.

16 GIBSON, R. W. (1975) Measurement of eriophyid mite populations on ryegrass using ultrasonic radiation. *Transactions of the Royal Entomological Society*, **127**, Part 1.

https://doi.org/10.23637/ERADOC-1-131

17 GREGORY, P. H. & (FRANKLAND, A. W.) (1973) Allergenic and agricultural implications of airborne ascospore concentrations from a fungus, *Didymella exitialis*. *Nature, London*, **245**, 336–337.

18 GOVIER, D. A. & KASSANIS, B. (1974) A virus-induced component of plant sap needed when aphids acquire potato virus Y from purified preparations. *Virology* **61**, 420–436.

19 GRIFFITH, R. L., HIDE, G. A., HIRST, J. M. & STEDMAN, O. J. (1974) Effects of gangrene (*Phoma exigua*) on potatoes. *Annals of Applied Biology* **77**, 237–250.

20 HIDE, G. A., & CORBETT, D. C. M. (1973) Controlling the early death of potatoes caused by *Heterodera rostochiensis* and *Verticillium dahliae*. *Annals of Applied Biology* **75**, 461–462.

21 JENKYN, J. F. (1974) A comparison of seasonal changes in deposition of spores of *Erysiphe graminis* on different trapping surfaces. *Annals of Applied Biology* **76**, 257–267.

22 JENKYN, J. F. (1974) Seasonal changes in infection of barley seedlings by *Erysiphe graminis* f.sp. *hordei*. *Annals of Applied Biology* **78**, 289–293.

23 JENKYN, J. F. (1974) Effects of mildew on the growth and yield of spring barley: 1969–72. *Annals of Applied Biology* **78**, 281–288.

24 JENKYN, J. F. & BAINBRIDGE, A. (1974) Disease gradients and small plot experiments on barley mildew. *Annals of Applied Biology* **76**, 269–279.

25 KASSANIS, B. & WHITE, R. F. (1974) Inhibition of acquired resistance to tobacco mosaic virus by actinomycin D. *Journal of General Virology* **25**, 323–324.

26 KASSANIS, B. & WHITE, R. F. (1975) Polyacrylic acid-induced resistance to tobacco mosaic virus in tobacco cv. Xanthi. *Annals of Applied Biology* **79**, 215–220.

27 KASSANIS, B., GIANINAZZI, S. & WHITE, R. F. (1974) A possible explanation of the resistance of virus-infected tobacco plants to second infection. *Journal of General Virology* **23**, 11–16.

28 KASSANIS, B. & WHITE, R. F. (1974) A simplified method of obtaining tobacco protoplasts for infection with tobacco mosaic virus. *Journal of General Virology* **24**, 447–452.

29 MCEWEN, J., SALT, G. A., & HORNBY, D. (1973) The effects of dazomet and fertiliser nitrogen on field beans (*Vicia faba* L.) *Journal of Agricultural Science, Cambridge* **80**, 105–110.

30 PEARSON, V. (1974) Virulence and cellulolytic enzyme activity of isolates of *Gaeumannomyces graminis*. *Transactions of the British Mycological Society* **63**, 199–202.

31 PLUMB, R. T. (1974) Properties and isolates of barley yellow dwarf virus. *Annals of Applied Biology* **77**, 67–111.

32 SALT, G. A. (1974) Etiology and morphology of *Geniculodendron pyriforme* gen. et. sp. nov., a pathogen of conifer seeds. *Transactions of the British Mycological Society* **63**, 339–351.

33 SALT, G. A. (1973) Conifer seedling pathology. In: *Report on Forest Research, London, 1972*, pp 150–152.

34 TURNER, R. H. & EDWARDS, C. A. (1974) Scanning electron microscope studies of Symphyla. In: Myriapoda. Proceedings of the Second International Congress of Myriapodology. *Symposia of Zoological Society, London* **32**, 135–142.

35 TURNER, R. H. & SMITH, C. B. (1974) A simple technique for examining fresh, frozen, biological specimens in the scanning electron microscope. *Journal of Microscopy* **102**, 209–214.

https://doi.org/10.23637/ERADOC-1-131