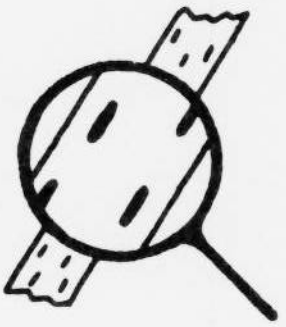
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1988 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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1988 Annual Report

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THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

The Survey, formerly the Physiologic Race Survey of Cereal Pathogens, commenced in 1967 following an unexpected epidemic of wheat yellow rust (*Puccinia striiformis*) which caused severe yield losses in the widely grown cultivar Rothwell Perdix. The epidemic was the result of the development of increased virulence for this previously resistant cultivar.

OBJECTIVES

The principal objective is the early detection of increased virulence compatible with those resistances currently being exploited in commercial cultivars and breeding programmes.

Secondary objectives include providing information for cultivar diversification schemes, monitoring the frequency of virulences and virulence combinations, measuring the effect of changes in cultivar on the pathogen population and detecting fungicide insensitivity in some pathogens.

METHODS

The Survey is carried out annually. In April, a list of cereal cultivars from which disease samples are requested is sent to about 100 pathologists and agronomists within the United Kingdom, who collect samples of infected leaves from field crops and cultivar trials and send them by post to the three testing centres:

- National Institute of Agricultural Botany, Cambridge, for yellow rust of wheat and barley.
- Institute of Plant Science Research, Cambridge, for mildew of wheat and barley.
- Institute for Grassland and Animal Production, Welsh Plant Breeding Station, Aberystwyth, for brown rust of wheat and barley, mildew and crown rust of oats and Rhynchosporium and net blotch of barley.

Other sampling methods are also used including mobile nurseries and the wind impaction spore trap.

At each centre, virulence is measured by inoculating seedlings and/or adult plants with spores multiplied from the disease samples.

Seedling tests are usually carried out under controlled environment conditions. Adult plant tests are carried out in the field, in Polythene tunnels or in controlled environment rooms.

RESULTS

The United Kingdom Cereal Pathogen Virulence Survey Committee meets annually to discuss the scientific and agricultural significance of the results of virulence tests carried out during the previous year. The results are used to

place winter wheat and winter and spring barley cultivars in diversification groups on the basis of their specific resistances. The results of the virulence tests and the diversification schemes are published shortly afterwards in the Annual Report.

The information provided by the Survey is used in various ways. Isolates possessing new virulences are used by the National Institute of Agricultural Botany to evaluate the resistance of cereal cultivars in trial in England and Wales. These isolates are also used by plant breeders to select lines with effective forms of resistance. Isolates are also supplied to Universities and Colleges for research projects and teaching purposes. Versions of the cultivar diversification schemes, modified to meet regional requirements, are published in the National Institute of Agricultural Botany Farmers Leaflet No. 8 'Recommended varieties of cereals', the Scottish Agricultural Colleges leaflet 'Recommended varieties of cereals', and by the Agricultural Development & Advisory Service.

EXPLANATION OF TERMS USED TO DESCRIBE RESISTANCE AND VIRULENCE IN THIS REPORT

Specific resistances and specific virulences

Resistance is the ability of a host cultivar to defend itself against infection by a pathogen isolate. Conversely, virulence is the ability of a pathogen isolate to infect a host cultivar.

Some cultivars possess resistance that is more effective against some isolates than others and this is termed 'specific' resistance. Similarly, some isolates are more able to infect some cultivars than others and this is termed 'specific' virulence.

The terms 'specific resistance factor' and 'specific virulence factor' are used to describe unidentified genes in host and pathogen which interact with one another. Specific resistance factors are numbered R1, R2 ... Rn and specific virulences are number V1, V2 ... Vn. Each individual specific resistance factor is effective against all isolates except those possessing the corresponding virulence factor. Hence a cultivar possessing R4 has effective resistance against all isolates except those possessing V4. Cultivars lacking specific resistances are classified as R0 and isolates lacking specific virulences are classified as V0.

Specific resistances and virulences relating to particular cereal diseases are described by additional prefixes for crop (W = wheat, B = barley and O = oats) and disease (M = mildew, Y = yellow rust, B = brown rust, C = crown rust, R = Rhynchosporium), hence WYR 2 and BMV 5.

Terms describing resistance at different growth stages

Resistances may also be classified according to the growth stages at which they are effective:

- overall resistances
  are effective at all growth stages

- seedling resistances
  are effective at seedling growth stages but ineffective at adult plant growth stages

- adult plant resistances
  are effective at adult plant growth stages but ineffective at seedling growth stages

SUMMARY OF RESULTS FOR 1988

Mildew of wheat

Virulence on cultivars carrying mildew resistance from the 1B-1R wheat-rye translocation (WMR 7, = Pm8) increased in frequency in 1988, whereas virulence on WMR 6 cultivars, which carry Pm6, declined.

The resistance of the wheat mildew pathogen to both triazole and morpholine fungicides increased in 1988.

Yellow Rust of Wheat

The frequency of the virulence WYV 9 increased sharply in 1988, reflecting the widespread cultivation of the susceptible cultivar Slejpner, which possesses the WYR 9 resistance derived from Rye. Virulence for the previously resistant cultivar Hornet was detected, attributable to a new virulence combination WYV 6,9. Brock proved very susceptible to a new isolate possessing the adult plant virulence WYV 14 in addition to WYV 7.

Brown Rust of Wheat

The winter wheat cultivars Fortress and Apollo carry WBR 1, whilst Mandate, Angler, Hornet and Slejpner appear to have additional adult plant resistance. Sober showed a response pattern similar to Sappo (WBR 3). Wembley, Alexandria, Minaret, Parade, Tonic and Riband displayed specific resistance.

Mildew of Barley

Most isolates collected in 1988 carried several virulences additional to those needed to infect the cultivars from which they were sampled. This indicates an urgent need for new resistance genes to be introduced into UK barley breeding programmes. The mlo resistance remained effective in Great Britain.

There was an increase in the resistance of the barley mildew pathogen to triazole fungicides throughout Britain, and in resistance to ethirimol and morpholines in most regions. Isolates with resistance to all three types of fungicide became more common in 1988.

In N.Ireland the most obvious change was an increase in the level of BMV 4,9, although this was not accompanied by noticeable infection of Atem in the field. There was no rise in resistance to triadimenol/fuberidazole seed-dressing.

Yellow Rust of Barley

The incidence of yellow rust of barley was extremely low in 1988 and no samples were received for testing.

Brown Rust of Barley

Results of adult plant field tests enabled several new spring barley cultivars to be placed in BBR groups. These included Delphine which was placed in Group IV with Simon (BBR 3) and Fergie in Group V with Corniche (BBR 10+?).

Rhynchosporium of Barley

The spring barley cultivar Joline was confirmed to carry BRR 1, also present in Armelle. Virulence to Digger was not found in the 1988 samples. Results of adult plant field tests suggest that Posaune and Panda may carry specific resistances.

Net Blotch of Barley

Isolates appeared to be more widely virulent than those from previous years. Seedling results suggested that some differential cutlivars can be grouped on the basis of similar patterns of response, with the implication that they carry common resistance factors. The susceptibility of Marinka was confirmed in adult plant field tests, where the newly introduced cultivars Puffin, Koala, Gaulois and Target were also susceptible to a netting isolate.

Mildew of Oats

The relatively complex race 5 (OMV 1,2,3) was again predominant. This race is able to attack all commercial oat cultivars. The only other virulence combination detected in 1988 was OMV 1,2 (race 3).

Crown Rust of Oats

All isolates tested were identified as race 251. This virulence combination is compatible with the differential cultivars Apler, Bond and Saia and occurs commonly in the UK.

MILDEW OF WHEAT

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Wheat mildew carrying the virulence which matches Pm8 (i.e. WMR7), the resistance gene in wheat varieties with the 1B/1R translocation, became more common during 1988, while the frequency of WMR6, the virulence matching Pm6, fell. Cv. Apollo carries Pm8.

Resistance to both triazole and morpholine fungicides increased during 1988. The highest levels of resistance to triazoles were found in the East Midlands, and the highest levels of resistance to morpholines in Northern England.

Identification of resistance phenotypes

The winter cultivar Apollo, which was first recommended by the N.I.A.B. in 1988, has WMR7 (Pm8) together with an additional resistance factor. Although it is not known if the additional resistance in Apollo is the same as that in cv. Slejpner, which also carries WMR7 and an additional, unidentified resistance, there is some evidence that this may be the case. Although no formal identification has been made, it seems likely that the newly recommended cultivars Pastiche and Riband have WMR2 (Pm2) (WMR = wheat mildew resistance factor; WMV = wheat mildew virulence factor).

Pathogen population structure

Table 1 shows the differential varieties used for pathogen identification and their resistance phenotypes.

Bulk isolates were taken from infected leaves sent in by UKCPVS co-operators, and tested on the set of differential varieties. Mean colony counts on the differentials, as percentages of colony numbers on cv. Cerco, are presented in Table 2.

Table 1. Differential cultivars, their wheat mildew resistance (WMR) group definitions and resistance genes.

WMR group	Gene	Cultivar
0	-	Alexandria, Cerco, Minaret
2	Pm2	Avalon, Fenman, Galahad, Longbow, Norman
4	Pm4	Armada
5	Pm5	Hope
7	Pm8	Ambassador
8	Mli	Mercia
2,6	Pm2,Pm6	Brimstone
2,7		Hornet, Mandate
4,8		Mission
2,4,6		Rendezvous
2,6,7		CWW 1645/5
2,6,8		Parade
2,Talent		Brock
7,?		Apollo, Slejpner
5,8,x		Tonic
Sona		Wembley
Axona		Axona

Isolates sampled from WMR2, WMR2,6 and WMR2,4,6 cultivars all have high levels of WMV2,6, WMV4, WMV2,4,6, WMV8 and WMV2,6,8. From these data, therefore, it appears that there is a fraction of the wheat mildew population which carries WMV 2, 4, 6 and 8. Isolates sampled from cv. Mercia (WMR8), however, had very low levels of WMV6. Although this might have come about if there were mildew clones which carried WMV8 but not WMV6, isolates from WMR2,6,8 cultivars had very low levels of WMV8. These apparently contradictory results are probably due to the inherent variability of the bulk isolate method. Few firm conclusions can be drawn from these data, therefore. It is clear that results, such as these, of bulk isolate tests must be supplemented or replaced by tests of single colony isolates if a proper understanding of the structure of the wheat mildew population is to be obtained.

The levels of virulence for cv. Slejpner (WMR7,?) are lower than those for WMR2,7 cultivars, except in samples from WMR8 and WMR2,6,8 cultivars and cv. Axona. This probably indicates that the WMV7 fraction of the pathogen population has not yet become fully adapted to cv. Slejpner.

Bulk isolates from WMR0 cultivars carry high levels of virulences matching certain spring cultivars (WMV5,8,x and WMV'Axona'), but no virulence for the spring cultivar Wembley (WMV'Sona') was detected. Inter-plot interference may account for the high levels of WMV5,8,x and WMV'Axona', since all WMR0 leaf samples were from trials of spring wheat, but there is no similar explanation for the absence of WMV'Sona'.

Table 2. Mean colony counts relative to cv. Cerco on seedlings inoculated with bulk isolates from a range of cultivars in trials.

WMR gp of host	WMV group of test seedlings										
	2,6	4	2,4,6	8	2,6,8	5,8,x	Ax.	Sona	2,7	7,?	2,Tal.
0	67	77	70	39	100	67	77	0	0	0	29
2	70	38	34	21	61	10	6	18	45	36	30
2,6	**96**	25	26	**25**	86	0	1	19	15	12	39
2,4,6	**41**	**44**	**43**	53	59	1	0	63	67	21	38
8	3	28	17	**37**	15	0	2	42	3	7	58
2,6,8	**119**	96	82	**8**	**154**	0	0	18	10	15	10
5,8,x	124	47	135	18	82	**53**	0	0	88	47	29
Axona	58	98	84	7	52	81	**66**	6	6	16	98
2,7	57	34	51	44	56	4	8	39	**87**	62	38
7,?	129	38	53	41	124	5	10	14	97	**86**	25
2,Tal	50	13	25	98	22	9	15	61	76	19	**90**

In order to examine changes in pathogen virulence frequencies through the year, nurseries of seedlings (cv. Cerco; WMR0) were exposed on a high roof at intervals, and bulk isolates collected from each nursery. The pathogenicity of these bulk isolates on the differential cultivars is shown in Table 3.

Given the variability of data from bulk isolate tests mentioned above, all but the largest differences in Table 3 must be treated with great caution. Three such differences are worth mentioning. There was a large fall in the level WMV2,6, which may reflect the declining popularity of WMR2,6 cultivars, such as cvs. Brigand and Brimstone. There were large rises in the levels of WMV2,7 and WMV7,? in the winter of 1987-8 followed by a fall in the spring and summer. This could be due to infections of mildew on autumn-sown crops of the corresponding cultivars (WMR2,7: Hornet; WMR7,?: Slejpner) which increased in popularity in 1987 and 1988. The later fall may indicate that, following heavy infections, farmers used fungicides to control mildew, but this interpretation can only be speculative. WMV5,8,x, WMV'Axona' and WMV'Sona' were all highest in

Table 3. Mean colony counts on test seedlings, as percentages of counts on cv. Cerco, when inoculated with bulk isolates collected from seedlings of cv. Cerco exposed on the roof of a high building in Cambridge.

Season	WMR group of test seedlings											
	2	4	2,6	2,4,6	8	2,6,8	2,7	7,?	2,Tal.	5,8,x	Ax.	Sona
1987												
autumn	73	93	53	39	34	80	7	0	34	17	9	32
winter	52	79	27	38	18	59	1	4	6	63	67	23
1988												
spring	68	58	26	26	42	65	0	5	40	29	21	36
summer	71	42	20	23	12	65	32	48	51	35	27	30

the summer. The matching resistances are only carried by spring cultivars. The relative infection rates on cv. Cerco cannot easily be translated into frequencies of virulence genes, since no random sample of wheat mildew single colony isolates has been collected and analysed for several years.

Severe mildew infections were reported on cultivars with WMR7 (Pm8) in 1988. In Table 4, virulences of bulk isolates from some of these cultivars are compared. All isolates had high levels of WMV2,7. The relatively high levels of WMR2,7 on cvs. Apollo and Haven were probably due to experimental variation, because more samples from cvs. Hornet, Mandate and Slejpner were tested. Virulence for cv. Slejpner (WMV7,?) was more common in isolates from cvs. Slejpner and Apollo than in those from cvs. Hornet, Mandate and Haven. Despite the apparent similarity of their mildew populations, the variability of the bulk isolate method means that it is not possible to conclude that cv. Apollo shares an additional resistance with cv. Slejpner. Differences in the levels of WMV2,6, WMV2,4,6 and WMV2,6,8 were also observed, the most noticeable being the lack of WMV2,4,6 in isolates from cv. Haven. There is no known reason for this discrepancy. In previous years it appeared that there were two distinct types in the wheat mildew population, one carrying WMV2, 4, 6 and 8 and the other carrying WMV7, but it now seems that many isolates sampled from WMR7 cultivars also carry WMV 2, 4, 6 and 8.

Table 4. Colony counts, as percentages of counts on cv. Cerco, on test seedlings inoculated with bulk isolates sampled from Pm8 (WMR7) cultivars.

Source cultivar	Test varieties					WMR group
	Brimstone 2,6	Rendezvous 2,4,6	Parade 2,6,8	Hornet 2,7	Slejpner 7,?	
Hornet	49	52	57	86	47	
Mandate	69	49	54	89	83	
Slejpner	104	56	136	90	89	
Apollo	214	120	125	137	150	
Haven	138	6	140	97	55	

Pathogen response to fungicides

Bulk isolates collected from seedlings of cv. Cerco exposed on the roof of a high building in the centre of Cambridge were tested on seedlings of cv. Cerco treated with a range of fungicides. Changes throughout the year were examined.

In Table 5, results of tests of bulk isolates on seedlings treated with triadimenol are presented. Colony counts on seedlings treated with the lowest

dose varied through the year, but were high at all times. This variability may be due to random effects of the bulk isolate method. It is possible that all strains of wheat mildew are now resistant to the 0.04 g triadimenol / kg seed dose in this experimental system. The highest levels of resistance to 0.125g triadimenol / kg seed were found in the summer seasons and in autumn 1988, coinciding with the time of maximum exposure of the pathogen population to fungicides. Resistance to the field rate, 0.375 g triadimenol / kg seed, rose in 1988, possibly as a result of continued selection pressure by triazole fungicides. Isolates sampled in summer and autumn 1988 were more resistant to the field rate than were the control resistant isolates.

Table 5. Colony counts on seedlings of cv. Cerco, treated with different doses of triadimenol, as a percentage of counts on untreated seedlings, when inoculated with bulk isolates collected from untreated seedlings of cv. Cerco exposed on a high roof in Cambridge.

Season collected	Dose of triadimenol in g/kg seed of cv. Cerco 0.04	0.125	0.375
1987 spring	83	8	0
summer	133	25	3
autumn	66	2	0
winter	47	9	1
1988 spring	84	13	0
summer	54	26	33
autumn	83	50	17
Control) sensitive	0	0	0
isolates) resistant	146	88	3

Bulk isolates of wheat mildew from different regions were sampled by exposing seedlings of cv. Cerco in the wind impaction spore trap (WIST), which was mounted on a car and driven over a number of routes in England. Bulk isolates from Northern England continued to be less resistant to triadimenol than those from East Anglia and the East Midlands (Table 6). Although isolates collected in 1988 were generally less resistant than those collected in 1987, the resistance of the control isolates also apparently fell between 1987 and 1988. This is probably a consequence of using different batches of treated seed in the two years. Taking this into account, the population of wheat mildew increased in resistance to the lowest dose of triadimenol. There was a rise in resistance to the intermediate dose (0.125 g/kg) in East Anglia, but not elswhere. Resistance to the highest dose (the rate used commercially) continued

Table 6. Colony counts on seedlings of cv. Cerco, treated with different doses of triadimenol, as a percentage of counts on untreated seedlings, when inoculated with bulk isolates collected from untreated seedlings of cv. Cerco exposed in the wind impaction spore trap (WIST).

	Dose of triadimenol in g/kg seed of cv. Cerco 0.04		0.125		0.375	
	1987	1988	1987	1988	1987	1988
East Anglia	62	56	16	20	3	1
East Midlands	77	80	64	32	6	7
Northern England	72	69	26	7	0	0
Control) sensitive	0	0	0	0	0	0
isolates) resistant	116	71	63	33	10	0

to be rare, but rose in the East Midlands. Overall, the highest rates of resistance to triadimenol were found in the East Midlands in both years.

The resistance of wheat mildew populations to morpholine fungicides was also studied. Table 7 shows results of tests of bulk isolates inoculated onto seedlings treated with sprays of fenpropimorph (formulated as Corbel) or fenpropidin (formulated as Patrol). Although the doses of the morpholine fungicides used in these experiments was very low, there was a clear trend of increased resistance to morpholines in 1988. Strains carrying resistance to morpholines survived the winter of 1987-88 and provided a source of infection on wheat in the spring. These results reflect the increased use of morpholines fungicides by farmers.

Table 7. Colony counts on seedlings of cv. Cerco, treated with fenpropimorph or fenpropidin, as a percentage of counts on untreated seedlings, when inoculated with bulk isolates collected from untreated seedlings of cv. Cerco exposed on a high roof in Cambridge.

Time of collection	Treatment of test seedlings (proportion of field rate) Fenpropimorph (1/100)	Fenpropidin (1/50)
1987 spring	0	0
summer	0	0
autumn	2	0
winter	16	1
1988 spring	17	5
summer	44	16
autumn	67	50
Control) sensitive	0	0
isolates) resistant	42	13

Table 8 compares bulk isolates collected in different parts of the country by exposing seedlings in the WIST. Unlike previous years, resistance to fenpropimorph was greater in the East Midlands and Northern England than in East Anglia. Many figures in Table 8 are higher than the corresponding values for the resistant control isolates. It is not possible to compare the levels of resistance directly, because the control isolates were single colony isolates, whereas the test samples were bulk isolates. Further tests are in progress with single colony isolates to determine whether there has indeed been a shift in the degree of resistance.

Table 8. Colony counts on seedlings of cv. Cerco, treated with fenpropidin or fenpropimorph, as percentages of counts on untreated seedlings, when inoculated with bulk isolates collected from untreated seedlings of cv. Cerco exposed in the wind impaction spore trap (WIST).

Region	Treatment of test seedlings (proportion of field rate) Fenpropimorph (1/100) 1987	1988	Fenpropidin (1/50) 1987	1988
East Anglia	0	28	0	0
East Midlands	20	11	19	0
Northern England	18	27	30	24
Control) sensitive	3	0	8	0
isolates) resistant	10	1	18	4

YELLOW RUST OF WHEAT

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National Institute of Agricultural Botany

The frequency of WYV 9 rose sharply, reflecting widespread cultivation of the susceptible WYR 9 cultivar Slejpner. Virulence for Hornet was detected for the first time, associated with a new virulence combination WYV 6,9. In adult plant tests, Brock (WYR 7) proved very susceptible to a new isolate possessing WYV 14 in addition to WYV 7.

INTRODUCTION

The principal aim of the wheat yellow rust survey is to detect increased virulence for specific resistances to Puccinia striiformis (WYR factors). At the same time, specific resistances in current and new cultivars are identified and the information used to devise a varietal diversification scheme. Specific resistances identified to date, the resistance genes where known, differential cultivars possessing each resistance and the year of first detection of virulence (WYV) in the UK population of P.striiformis are given in Table 1.

Table 1 Resistance factors to Puccinia striiformis and differential cultivars.

WYR Factor	Gene	Type*	Differential Cultivar(s)**	WYV detected
WYR 1	Yr 1	0	Chinese 166, Maris Templar	1957
WYR 2	Yr 2	0	Heine Vll, Brigand	1955
WYR 3	Yr 3a + 4a	0	Vilmorin 23, Cappelle Desprez	1932
WYR 4	Yr 3b + 4b	0	Hybrid 46, Avalon	1965
WYR 5	Yr 5	0	T. spelta album	
WYR 6	Yr 6	0	Heines Kolben, Maris Ranger	1958
WYR 7	Yr 7	0	Lee, Tommy	1971
WYR 8	Yr 8	0	Compair	1976
WYR 9	Yr 9	0	Riebesel 47/51, Clement	1974
WYR 10	Yr 10	0	Moro	
WYR 11	-	A	Joss Cambier	1971
WYR 12	-	A	Mega	1969
WYR 13	-	A	Maris Huntsman	1974
WYR 14	-	A	Hobbit	1972
Additional test cultivars 1988				
WYR 1,2,4			Brimstone	
WYR 9			Slejpner	
WYR 1,9			Stetson	
WYR R			Hornet, Parade, Fortress	

* 0 = Overall A = Adult Plant.

** Differential cultivars used in 1988 seedling tests are underlined.

METHODS

Methods used at NIAB for virulence tests have been described by Priestley, Bayles and Thomas (1984).

1988 isolates

1988 was an epidemic year for wheat yellow rust, with severe outbreaks in the Eastern counties of England. The epidemic was largely associated with the susceptible cultivar Slejpner, which was grown on a large proportion of the acreage (approximately 25%).

175 samples were received, of which 56 were from Slejpner. Isolates made from 71 of the samples were analysed for virulence in seedling tests, using the differential cultivars indicated in Table 1. 43 samples, which were either repeats of those tested earlier in the season or multiple samples from cultivar trials, were stored for testing at a later date. 61 samples, a high proportion of which originated from fungicide-treated crops, failed to establish.

1987 isolates

10 isolates were tested on adult plants of 30 cultivars in Polythene tunnels and on seedlings of the same cultivars in controlled environment chambers. The isolates comprised three control isolates of known virulence and seven new isolates from the 1987 survey (Table 2).

Table 2 Isolates of P.striiformis used in adult plant tests

Isolate Code	Source Cultivar	Site	WYV Factors*
83/10	Hammer	Oxford	1,2,3,9,(13)
83/62	Longbow	Norfolk	1,2,3,6,13
84/1	Brimstone	Lincolnshire	1,2,3,4,6
87/13	Slejpner	Lincolnshire	1,2,3,9
87/22	Stetson	Oxfordshire	1,2,3,9
87/27	Galahad	Norfolk	1,2,3,4,6
87/56	Longbow	E.Scotland	1,2,3,4,6
87/59	Galahad	E.Scotland	1,2,3,4,6
87/66	Slejpner	Lincolnshire	1,2,3,9
87/69	Rifle	E.Scotland	2,3,4,6,7

*determined from seedling tests and previous years' adult plant tests (pre-1987 isolates only)

RESULTS

1988 isolates

The survey is not a random population sample and changes in virulence frequency from year to year (Table 3) should therefore be interpreted with caution.

Table 3 Virulence factor frequency (%)

WYV Factor	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988
WYV 1	73	73	83	95	71	63	85	75	76	78	87	68
WYV 2	100	97	100	100	100	100	100	100	100	100	100	100
WYV 3	100	100	100	85	95	100	100	100	100	100	100	100
WYV 4	24	27	17	15	29	37	20	31	45	70	47	78
WYV 5	0	0	0	0	0	0	0	0	*	*	*	*
WYV 6	16	26	17	25	31	29	26	64	90	96	89	72
WYV 7	8	0	0	0	5	5	0	3	3	22	8	6
WYV 8	4	0	0	0	0	2	0	0	*	*	*	*
WYV 9	0	0	0	0	5	2	23	31	3	4	5	66
WYV 10	0	0	0	0	0	0	0	0	*	*	*	*
Hornet	WYR (R)							*	*	0	0	42
No. of isolates tested	26	66	30	20	42	41	63	36	29	23	52	71

* = differential not included in test

There was a dramatic increase in the frequency of WYV 9 from 5% in 1987 to 66% in 1988. This was associated with the yellow rust epidemic on the WYR 9 cultivar Slejpner.

Virulence for Hornet was detected for the first time, in 42% of the isolates tested. (The earlier report of Hornet virulence in the 1987 Annual Report was not confirmed when the isolate concerned was re-tested. The relevant entry in Table 3 has been amended accordingly). All but one of the isolates virulent on Hornet were of two types, either WYV 2,3,4,6,9 or WYV 1,2,3,4,6,9 both of which differ from all earlier UK isolates in possessing combined virulence for WYR 6 and WYR 9. This evidence, together with knowledge of Hornet's parentage, indicates that the variety possesses the WYR 9 resistance derived from Rye, together with WYR 6.

The single Hornet-virulent isolate which proved to be an exception to the above pattern had the virulence composition WYV 1,2,3,6, being avirulent on the WYR 9 differential Clement. It has been suggested elsewhere that Clement possesses one or more specific resistances in addition to WYR 9. This could explain the apparent anomoly of an isolate which is virulent on Hornet (WYR 6,9) but avirulent on Clement (WYR 9,x).

Adult plant tests

The results of adult plant tests are given in Table 4. Yellow rust levels in polythene tunnels were lower than usual, largely due to severe mildew infection.

Nine cultivars exhibited a high level of adult plant resistance to all isolates. Of these, Hornet, Mandate, Fortress and Parade were also resistant to all isolates as seedlings. In contrast, Rendezvous, Pastiche, Mercia, Apostle and Angler were either seedling susceptible to all isolates or possessed specific resistances which were overcome at the seedling stage by isolates with matching virulence. It is of course impossible to predict the durability of the adult plant resistance of these cultivars, but some have maintained their resistance after several years of commercial production, whilst others have been overcome by the pathogen at a relatively early stage.

Cultivars possessing WYR 9 interacted with four WYV 9 isolates. Slejpner appeared to be relatively susceptible to two of these isolates which originated from crops of Slejpner (87/13 and 87/66) and also gave high levels of infection on the WYR 13 cultivars Riband and Hustler. However, it is difficult to judge whether these isolates genuinely possess increased virulence for Slejpner, since they tended to give higher infection levels on all WYR 9 cultivars. In addition, isolate 83/10, which gave only a very low infection on Slejpner this year, has given high levels in previous years. The question of whether isolates collected from Slejpner during the 1988 epidemic show a further adaptation to the cultivar cannot be resolved until the completion of adult plant tests in 1989.

For the first time, high levels of infection were recorded on the WYR 7 cultivar Brock, with a new isolate (87/69) which also gave increased infection on Maris Huntsman (WYR 13) and Hobbit (WYR 14). Taken in conjunction with information on its parentage, this evidence indicates that Brock possesses the adult plant resistance WYR 14 in addition to WYR 7.

Seven 1987 isolates were tested, four of which possessed combined virulence for the two major adult plant resistances WYR 13 and WYR 14. These four isolates (87/59, 87/27, 87/66 and 87/69) represented previously unidentified virulence combinations, continuing the trend towards increasing complexity noted in the 1987 Annual Report. The same trend is evident in seedling virulence frequency data which show that the average number of virulence factors per isolate has risen from 2.5 in 1966 to 4.8 in 1988, resulting in a yellow rust population which is broadly adapted to a wide range of cultivars. Effective diversification is likely to become increasingly dependent on the availability of cultivars with good levels of resistance to all races, such as those in DG 1.

FUNGICIDE INSENSITIVITY (HGCA - sponsored project)

An *in vivo* biossay has been developed for screening isolates for variation in sensitivity using intact seedlings sprayed with fungicide prior to inoculation with spores of *Puccinia striiformis*. Approximately 100 isolates of wheat yellow rust, collected since the early 1960's, have now been tested for insensitivity to triadimenol and fenpropimorph. Only a small number of isolates showed statistically significant differences when compared with a standard control isolate and present indications are that these differences are slight. There does not appear to be a consistent relationship between the age of an isolate and its sensitivity. The next step will be to subject isolates selected from the preliminary screen to more precise tests in order to estimate and compare $E.D_{50}$ values.

REFERENCES

Priestley, R.H., Bayles, R.A. and Thomas, J.E. (1984). Identification of specific resistances against *Puccinia striiformis* (Yellow Rust) in winter wheat varieties. 1. Establishment of a set of type varieties for adult plant tests. *Journal of the National Institute of Agricultural Botany*, *16*, 469-476.

Table 4. Results of Adult Plant Tests 1988

Values are per cent leaf area infection (mean of 4 assessment dates)

Cultivar	Isolate and WYV Factors	83/62 1,2,3,6,13	84/1 1,2,3,4,6	87/56 1,2,3,4,6	87/59 1,2,3,4,6,13,14	87/27 1,2,3,4,6,13,(14)	83/10 1,2,3,9,13	87/22 1,2,3,9,13	87/13 1,2,3,9,13	87/66 1,2,3,9,13,14	87/69 2,3,4,6,7,13,14
Hornet	R (?6,9)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mandate	R (?6,9)	2.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fortress	R (?6,9)	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.1	0.1
Parade	R	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0
Rendezvous	0 + APR	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0
Pastiche	0 + APR	0.0	0.0	0.0	0.6	0.3	0.1	0.0	0.0	0.4	0.0
Apostle	2,6 + APR	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.0	0.0
Angler	1,9 + APR	0.0	0.0	0.0	0.1	0.0	0.5	0.0	0.0	0.7	0.4
Mercia	?3 + APR	0.0	0.0	0.0	0.5	0.4	0.2	0.0	0.0	0.0	0.1
M.Templar	1	0.1	0.9	0.5	2.7	4.4	4.6	1.6	0.6	7.0	0.0
M.Beacon	4	0.0	2.3	4.2	3.1	5.0	0.4	0.6	0.0	1.1	14.0
Brimstone	1,4	0.5	11.7	4.0	4.6	3.5	0.0	0.4	0.4	0.0	0.0
Galahad	1,2,14	0.0	0.0	0.9	3.3	5.3	0.0	0.1	0.0	1.2	0.0
Avalon	4,14	0.0	0.0	1.3	0.4	1.0	0.0	0.0	0.0	0.0	0.7
Kinsman	6,13	1.3	0.0	2.2	4.1	5.4	0.0	0.4	1.0	1.5	12.0
Norman	2,6	5.0	2.5	6.0	5.6	10.0	0.0	*	0.1	0.3	7.4
Longbow	1,2,6,13	7.7	0.0	1.1	4.4	1.9	0.0	0.0	0.0	2.5	0.1
M.Huntsman	2,13	1.1	0.1	0.9	2.4	3.5	0.3	0.2	0.0	1.3	9.2
Riband	13	1.6	0.0	*	1.9	2.0	2.4	2.6	8.6	9.4	10.7
Hustler	1,13	0.5	0.0	*	3.0	4.1	4.5	2.5	5.8	6.6	0.0
Hobbit	14	0.0	0.0	1.4	4.1	0.3	1.6	0.0	2.2	11.7	10.7
Clement	9	0.0	0.0	0.2	0.1	0.0	8.0	12.2	*	32.2	0.0
Slejpner	9	0.0	0.0	0.0	0.0	0.1	0.1	0.6	12.5	10.7	0.0
Apollo	9	0.0	0.0	0.0	0.0	0.0	0.9	4.1	3.1	8.5	0.0
Stetson	1,9	0.0	0.0	0.0	0.0	0.0	8.4	7.6	21.7	15.9	0.0
Tommy	7	0.0	0.1	0.0	0.0	0.0	3.5	0.4	0.0	0.5	14.2
Brock	7,?14	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.6	3.6	19.9
Armada	12	0.0	0.0	0.0	0.0	0.4	0.0	0.2	0.0	0.0	0.0
Cappelle	3	0.0	0.0	0.4	0.5	0.4	2.3	0.0	0.0	4.9	0.1
Michigan Amber	0	3.9	7.4	6.6	4.2	6.8	4.9	4.6	2.7	7.7	16.5

R = resistant to all isolates

* = missing plot

BROWN RUST OF WHEAT

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The twenty-six isolates of P. recondita successfully cultured were tested on seedlings of the differential cultivars. Results of these tests, together with information from two adult plant isolation nurseries enabled the resistances present in specific wheat cultivars to be classified. The winter wheat cvs Fortress and Apollo carry WBR-1, whilst cvs Mandate, Angler, Hornet and Slejpner appear to have additional adult plant resistance. Cv. Sober showed a response pattern similar to cv. Sappo (WBR-3). Cv. Gamin (overall resistance WBR-6), although seedling susceptible to isolate WBRS-87-9, was resistant in the adult plant field tests. Other cvs to display specific resistance included Wembley, Alexandria, Minaret, Parade, Tonic and Riband.

SEEDLING TESTS WITH 1988 ISOLATES

Thirty two leaf samples of Puccinia recondita were received in 1988. These included 25 sent from the MAFF Cereal Survey specifically for fungicide insensitivity screening at the East of Scotland College of Agriculture (Dr J. Gilmour, HGCA funded project). The samples were from the following ADAS regions of England: 22 from the East, 6 from the South-West and 4 from the South. The majority of the infected leaves received had been sampled from 3 winter wheat cultivars, Avalon (10), Mercia (7) and Galahad (7). The remainder came from Brock (4), Slejpner (1), Sperber (1), Breeding line (1) and Rye (1). Isolates were obtained from 26 of the samples and were tested on differential cultivars which comprised the standard WBR reference cultivars, cv. Thatcher backcross lines carrying specific Lr resistance factors, and 17 other spring and winter wheat cultivars from the NIAB Recommended List and Recommended List trial material (Table 1).

Table 1. Differential cultivars

Standard differential cultivars		Thatcher Lr lines	Spring and winter cultivars
Clement	(WBR-1)	Lr 1	Axona
Maris Fundin	(WBR-2)	Lr 2a	Jerico
Norman	(WBR-2)	Lr 3	Wembley
Hobbit	(WBR-2)	Lr 3bg	Canon
Sappo	(WBR-3)	Lr 3ka	Sober
Maris Halberd	(WBR-4)	Lr 9	Slejpner
Gamin	(WBR-6)	Lr 15	Mercia
Sterna	(WBR-7)	Lr 19	Parade
Sabre	(WBR-7)	Lr 24	Rendezvous
Armada	(WBR-0)		Apollo
			Fortress
			Mandate
			Angler
			Riband
			CNW 4466/1425
			CNW 4643/2826

The tests were carried out under two post-inoculation environments: a low temperature regime (10°C and 12 h photoperiod) and a high temperatures regime (25°C and 16 h photoperiod).

Results

Isolate/cultivar interactions were classified on the standard 0-4 scale as resistant (R:0-2) or susceptible (S:3-4). In cultivars with temperature-sensitive resistance factors (WBR-2,3,4 and 7), interactions were classified as susceptible only if that reaction was expressed at both temperatures. The data are presented in Table 2.

Table 2. Classification of seedling reactions of differential cultivars to 1988 pathogen isolates

Cultivar	WBR factor	Virulence combination				Virulence frequency
Clement	1	R	R	R	R	0
Fundin	2*	S	R	S	S	0.96
Norman	2*	S	R	R	R	0.85
Hobbit	2*	S	R	R	S	0.88
Sappo	3*	R	R	R	R	0
Halberd	4*	R	R	R	R	0
Gamin	6	S	S	S	S	1.00
Sterna	7*	R	R	R	R	0
Sabre	7*	R	R	R	R	0
Armada	0	S	S	S	S	1.00
No. of isolates		22	1	2	1	

*Temperature sensitive

None of the isolates was virulent on cv. Clement (WBR-1), although several isolates gave a mixed resistant reaction due to a mixture of races. Other cultivars giving a similar pattern of response included the winter cvs Apollo, Fortress, Mandate, Angler and Slejpner. Isolate WBRS-88-15, received from cv. Slejpner (WBR1+ additional adult plant resistance), failed to infect any of the WBR-1 cultivars in seedling tests.

The temperature-sensitive resistance WBR-2, present in cvs Maris Fundin, Norman and Hobbit was effective at both temperature regimes to only one of the isolates whereas it was effective to two and three of the isolates in cvs Hobbit and Norman respectively at the high temperature only. All reactions of these particular isolates were of a mixed resistant or mixed susceptible nature on all three cultivars. These cultivars have previously been separated on their reactions to certain isolates (Clifford et al., 1982), cvs Norman and Hobbit reacting more alike. These results further support the view that these cultivars carry common WBR-2 resistance factors but differ in specific modifying factors.

The resistances of cv. Sappo (WBR-3) and Maris Halberd (WBR-4), which are more effective at the lower temperature, were not overcome by any of the isolates at 10°C. Eleven isolates were more virulent on cv. Sappo at 25°C, often giving a mixed susceptible reaction as opposed to a mixed resistant reaction on cv. Halberd. The spring wheat cvs Sober and Canon gave a pattern of response similar to that of cv. Sappo whereas cv. Wembley, which gave an identical pattern of response to the

isolates tested in 1987 (Jones and Clifford, 1988), appeared to be more susceptible, particularly at the higher temperature regime, to the 1988 isolates. All the 1988 isolates were virulent on cv. Gamin (WBR-6).

Cultivars Sabre and Sterna (WBR-7) were resistant to all isolates at 25°C but virulence was expressed in isolate WBRS-88-11 at 10°C, although this was of a mixed susceptible type. The spring wheat cv. Jerico was resistant at both high and low temperature regimes to all the isolates. The winter wheat cvs Parade and Mercia were susceptible to all isolates tested in 1988.

Of the nine Thatcher backcross lines, which carry known specific Lr genes, the resistance conferred by Lr 1, Lr 3bg, Lr 9, Lr 19 and Lr 24 was effective against all isolates at both 10°C and 25°C. The temperature sensitive resistance of Lr 2a was more effective at the higher temperature whilst the converse was true of Lr 15, and this confirms previous observations.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Two isolates were tested on adult plants in field isolation nurseries in 1988. The isolates used were:

Isolate	Origin
WBRS-87-3 (WBV-2,3,4,5,6,8,9)	Cv. Mercia, Terrington EHF, Norfolk
WBRS-87-9 (WBV-2,5)	Cv. Avalon, Wingham, Canterbury, Kent

Each nursery comprised 28 winter and 10 spring wheat cultivars. Assessments of percentage infection and reaction type were made throughout the season.

Results

These are summarised in Table 3. Infection levels within the nursery inoculated with isolate WBRS-87-9 were lower than those in the other nursery, particularly amongst the spring cultivars where brown rust was slow to develop.

WBR-1 Resistance: The winter wheat cv. Apollo showed a pattern of response to the two isolates similar to cvs Fortress and Clement (WBR-1). Cvs Hornet, Mandate and Angler, which were classified on 1988 seedling tests as carrying WBR-1, gave a pattern of response similar to that of cv. Slejpner, which carries WBR-1 and additional resistance which is only expressed at the adult plant stage of growth. The interpretation of the results is that low levels of infection on cvs Clement, Fortress and Apollo resulted from ingress of WBV-1 pathotypes into the nursery that were avirulent on the cv. Slejpner sub-group.

WBR-2 Resistance: Both isolates carry WBV-2 which was shown by the susceptibility of the type-cultivar Fundin. Cvs Hobbit and Norman were relatively resistant to WBRS-87-9 indicating that they carry additional resistance factors. Other cultivars showing similar quantitative responses were Mercia, Galahad, Longbow and Brock but this in itself is insufficient data to classify these cultivars in WBR-2.

WBR-3/4 Resistance: The spring wheat cvs Sappo (WBR-3) and Halberd (WBR-4) were both more susceptible to isolate WBRS-87-3 which carries the corresponding virulence genes, not present in isolate WBRS-87-9. Cv. Sober was also more susceptible to this isolate, thus confirming seedling tests that it may carry the same resistance gene as cv. Sappo.

The spring wheat cv. Canon which was also thought to have this resistance by its response in seedling tests, was resistant in both nurseries.

In confirmation of previous years' results, cv. Wembley was susceptible to isolates carrying WBV-3 and WBV-4. Other cultivars more susceptible to isolate WBRS-87-3 in field tests were Alexandria, Minaret, Parade, Tonic and Riband although seedling tests indicate that these cultivars do not possess WBR-3 or WBR-4.

Cv. Gamin (WBR-6) was resistant in the field to isolate WBRS-87-9 although susceptible in seedling tests. The resistance, when effective, has previously been classified as of the overall type. However, to isolate WBRS-87-9, the resistance appears to express only at post-seedling stages. This phenomenon of overall resistance to some isolates and adult plant resistance to others may be more common than is apparently the case, but a wider range of adult plant tests using a larger number of pathotypes would be necessary to clarify the position. Isolate WBRS-87-3 (WBV-9) was virulent on cvs Avalon, Parade and Riband which were resistant to isolate WBRS-87-9, indicating that they carry the same resistance.

The resistance of the winter wheat cvs Apostle, Pastiche, Rendezvous and Brimstone was effective against both isolates as was that of the spring cvs Axona and Jerico. These tests, together with those from previous years indicate that their resistance is effective against WBV factors 1,2,3,4,6 and 9. In addition, from the susceptible reactions of Huntsman (WBR-5) and Ranger (WBR-8) to isolate WBRS-87-3 it appears that this group of cultivars carries either WBR-7 (in cv. Sabre) or an as yet unclassified resistance.

REFERENCES

CLIFFORD, B.C., NAZIM, M.M. & JONES, E.R.L. (1982). Brown rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1981 Annual Report, pp.30-36.

JONES, E.R.L. & CLIFFORD, B.C. (1988). Brown rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1987 Annual Report, pp. 17-21.

Table 3. Percentage infection of winter and spring* wheat cultivars by specific isolates of Puccinia recondita in field isolation nurseries in 1988.

Cultivar	WBR factor	Isolate WBRS-87-3 (WBV 2,3,4,5,6,8,9)	WBRS-87-9 (WBV 2,5)
Clement	1	5	0
Fortress		6	0
Apollo		4	0
Slejpner	1+	0	0
Hornet		0.1	0
Mandate		0	0
Angler		0	0
Fundin	2	46	31
Hobbit		33	12
Norman		22	6
Sappo*	3	21	1
Sober*		23	2
Halberd*	4	30	3
Huntsman	5	42	28
Gamin	6	22	0.1
Sabre	7	0	0
Sterna		0	0
Ranger	8	34	0
Kinsman	8?	31	0
Avalon	9	36	1
Apostle		0	0
Pastiche		0	0
Jerico*		0	1
Canon*		0	Trace
Rendezvous		Trace	0
Axona*		0	0.25
Brimstone		2	0.1
Wembley*		13	Trace
Alexandria*		17	0.1
Minaret*		18	0.5
Parade		22	0
Tonic*		26	0
Riband		35	3
Mercia		31	17
Galahad		33	12
Longbow		36	18
Brock		40	17
Armada		41	30

Mean of 3 replicates, 3 assessment dates (winter cvs)
" " "4 replicates, 2 assessment dates (spring cvs; isolate WBRS-87-3)
4 replicates, 1 " " (" " ; isolate WBRS-87-9)

BROWN RUST OF WHEAT : FUNGICIDE SENSITIVITY (HGCA-sponsored project)

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The sensitivities of isolates of wheat brown rust, collected during 1987, to triadimefon and propiconazole were determined (EC50s) in tests with detached leaf segments and compared with those of some isolates collected before 1987. Preliminary results have been published (Boyle et al, 1988) and are summarised here.

There was a 20-fold difference of sensitivity to triadimefon between the most sensitive and the least sensitive isolates, but only a six-fold range of sensitivity to propiconazole. The earlier isolates were the most sensitive to both fungicides. Pustule production of some isolates was stimulated at the lower fungicide concentrations.

REFERENCE

BOYLE F, GILMOUR J, LENNARD J H, CLIFFORD B C and JONES E R L (1988) Sensitivity of cereal brown rust fungi to triadimefon and propiconazole. Brighton Crop Protection Conference - Pests and Diseases - 1988, 1, 379-384.

MILDEW OF BARLEY

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Isolates carrying virulence for cv. Camargue were identified for the first time; Camargue carries BMR10a (M1-a13) from cv. Rupee and BMR6c (M1-(Ab))from cv. Triumph. Isolates sampled from many varieties carry several additional virulences, which allow them to grow on varieties other than that from which they were sampled. The high frequency of unnecessary virulences emphasises the urgent need for new resistance genes to be introduced into U.K. barley varieties.

There was an increase in the level of resistance to triazole fungicides in all regions where samples were collected. Resistance to ethirimol increased in all regions except Eastern Scotland. The response to morpholine fungicides was more variable, but there has been an increase in resistance to fenpropimorph in all regions since 1986. Isolates have been identified with resistance to all three groups of fungicides. These may have been selected through the extensive use of mixtures of fungicides with different modes of action.

Identification of new resistance phenotypes

Of the winter barleys newly recommended by the N.I.A.B., cvs. Gaulois, Pastoral and Posaune have BMR1b (M1-ra, the resistance from W.41/145) alone, as do many other widely-grown winter barley varieties. Cv. Melusine has BMR2a (M1-g) and probably BMR1b. Cv. Puffin carries BMR1a (M1-h, the resistance from W.37/136) with BMR2a and BMR5 (M1-a12) (BMR = barley mildew resistance factor, BMV = barley mildew virulence factor).

The spring variety Prisma has BMR5 and BMR6c (M1-(Ab)), while cv. Hart is resistant to all isolates and probably has BMR9 (mlo).

Isolates with specific resistance for cv. Camargue, which was first recommended in Scotland in 1986, were found for the first time in 1988. Camargue has BMR10a (M1-a13) combined with BMR6c. This represents both a new identified resistance phenotype and a new combination of matching virulences.

It was previously reported that cv. Sherpa has BMR10b (M1-(Ru2)) and BMR5 (Wolfe et al, 1988) but this is now known not to be the case. Further tests have shown that cv. Sherpa has M1-a13 together with an additional resistance which has not yet been identified; it lacks BMR5.

There was no further evidence of increased pathogenicity for cultivars with the mlo resistance (BMR9). There were reports of infection on crops of cv. Atem, and some samples were received, but specific virulence was not confirmed in laboratory tests. This contrasts with recent results from Northern Ireland (Mercer, this Report).

Pathogen population structure

The differential varieties used for pathogen identification in 1988 and their resistance phenotypes are shown in Table 1.

The changes in the pathogen populations found on winter barley cultivars lacking major resistance genes (other than BMR1b [M1-ra]) since 1980 are shown in Table 2. These values are believed to reflect the frequencies of the various

Table 1. Barley Mildew Resistance groups for the differential cultivars used in the survey.

BMR gp	Gene	Cultivar	BMR gp	Gene	Cultivar
0	-	Golden Promise	7	Ml-al	Tyra
1a	Ml-h	W. 37/136	8	Ml-a9	Simon
1b	Ml-ra	W. 41/145	9	mlo	Apex
2a,2b	Ml-g,Ml-(CP)	Julia	10a	Ml-al3	Digger
3	Ml-a6	Midas	4,6b		Doublet
4	Ml-(La)	Lofa Abed	4,6a,6b		Klaxon
5	Ml-al2	Hassan	4,6a,7		Regatta
6a	Ml-k	H. 1063	4,8		Kym
6b	Ml-a7	Porter	5,6c		Natasha
6a,6b		Ark Royal	10a,?		Sherpa
6b,6c	Ml-a7,Ml-(Ab)	Triumph	10a,10b?		Pipkin

Table 2. Frequency, as mean colony counts relative to counts on cv. Golden Promise, of pathogenicity characters in populations from presumably non-selective winter barley cultivars for 1980 to 1988. ("-" = not tested).

Year	BMV character										
	2	3	4	5	6a	6b	6a,6b	6b,6c	7	8	10a
1980	61	27	16	21	-	-	38	2	5	0	-
1981	44	31	45	23	-	-	7	4	1	0	-
1982	48	45	31	41	-	-	18	4	1	0	-
1983	68	43	36	42	-	-	29	37	3	0	-
1984	47	51	15	13	-	-	52	52	1	1	-
1985	45	43	18	21	49	42	-	47	-	2	-
1986	28	23	8	24	26	23	-	24	1	2	0
1987	37	16	19	25	29	42	-	18	4	14	0
1988	54	25	45	42	45	41	30	16	20	14	0

virulence genes in the British population as a whole. There was an increase in the levels of BMV4, BMV5, BMV6a and BMV7 from 1987 to 1988, probably as a result of increased cultivation of cultivars with the corresponding resistance factors eg. Doublet, Klaxon, Regatta, Natasha (see Table 1), Blenheim, Corniche and Prisma (all BMR5,6c). The decrease in the level of BMV6b,6c continued, possibly because newer cultivars are replacing cv. Triumph. Although Natasha, Blenheim, Corniche and Prisma have BMR6c, they do not select for BMV6b, so the previously strong association of BMV6b and BMV6c is breaking down. The level of BMV3 continued to be low compared to its level in the early 1980s. This reflects the continuing absence of BMR3 cultivars.

BMV1b (V-ra) and BMV2a (V-g) are fixed (or nearly fixed) in the British population of barley mildew (Limpert, 1987; Brown, 1989). This is also shown by Table 3. The levels of BMV1b and BMV2a were similar in samples from winter barleys lacking the matching resistance characters (BMR1b or BMR2a), those with the matching resistances, and spring cultivars. The level of BMV1a (V-h) was lower on cultivars without the matching resistance than on those carrying it; BMV1a is not thought to be fixed in Great Britain.

Current associations and dissociations between virulence genes are shown in Table 4. Bulk isolates of powdery mildew were sampled from the cultivars of spring barley most commonly grown in commercial agriculture in England, and

Table 3. Mean colony counts, relative to counts on Golden Promise, on matching and non-matching hosts.

Collective host	BMV character 1a	1b	2a	2a,2b
Winter, non-matching cvs.	31	58	132	74
Spring, non-matching cvs.	43	51	143	75
Winter, matching cvs.	54	61	99	-
Spring, matching cvs.	-	-	153	-

tested on a differential set of varieties (Table 1). Scores were recorded as mean colony counts on each differential variety, compared to counts on cv. Golden Promise. Tests of isolates on differential varieties in the same BMR group as the host cultivar are highlighted in bold type. Year-to-year variation in these figures presumably reflects the inherent variability of the bulk isolate method.

The levels of BMVs 3 and 4 remained low in isolates sampled from cv. Triumph (BMR6b,6c), and the level of BMV6a decreased. BMV3 and BMV6a were once common

Table 4. Comparison of the populations of barley mildew found on some spring commercial cultivars in 1986, 1987 and 1988. Data are mean colony counts relative to counts on Golden Promise. ("-" = not tested).

BMR of host	year	BMV characters 3	4	5	6a	6b	6b,6c	7	8	10a	4,6	4,6a,7	4,8	5,6c
6b,6c	86	21	2	8	52	**41**	**50**	0	0	-	0	-	0	10
	87	6	1	3	52	**45**	**60**	0	0	0	1	0	0	54
	88	9	5	14	36	**78**	**59**	0	0	12	0	0	0	22
10	87	-	0	26	40	52	31	0	0	**60**	6	0	0	3
	88	1	0	0	60	46	8	0	90	**70**	0	0	0	0
4,6	86	8	**33**	41	**70**	**62**	3	0	27	-	**49**	-	24	8
	87	18	**45**	37	**46**	**35**	3	2	28	0	**56**	2	36	12
	88	12	**77**	44	**70**	**69**	9	6	17	0	**65**	11	16	21
4,6a,7	86	16	**32**	12	**63**	37	0	**106**	11	-	11	-	18	1
	87	29	**37**	18	**62**	56	9	**74**	39	0	41	**95**	58	16
	88	5	**66**	15	**73**	21	9	**85**	15	0	42	**107**	30	11
4,8	86	27	**38**	30	90	51	1	0	**69**	-	35	-	**79**	2
	87	14	**62**	42	58	45	0	1	**63**	0	34	1	**83**	5
	88	25	**80**	18	90	113	23	8	**89**	2	95	19	**84**	16
5,6c	86	8	5	**59**	14	45	35	1	0	-	1	-	0	**58**
	87	11	13	**42**	33	47	34	3	1	0	3	1	3	**79**
	88	3	8	**49**	37	37	25	4	0	1	3	4	3	**87**
10,6c	88	12	12	18	40	51	22	3	70	**85**	8	0	16	3

Cultivars in BMR groups: **6b,6c**: Triumph; **4,6**: Doublet, Joline, Klaxon, Montana, Oboe; **4,8**: Delphine, Kym; **4,6a,7**: Regatta; **5,6c**: Blenheim, Corniche, Fergie, Natasha, Prisma; **10**: Digger; **10,6c**: Camargue.

on cv. Triumph (Wolfe et al, 1986), but the levels of these unnecessary virulences have since declined. Similarly, pathogenicity for cv. Triumph (BMV6b,6c) remained low on cultivars without the M1-(Ab) gene. The reason for the increase in the level of BMV6b,6c in isolates sampled from BMR4,8 cultivars is not known.

Other than in isolates sampled from cv. Triumph, the frequencies of unnecessary virulences were greater than they were few years ago. For example, BMVs 5 and 8 were common in isolates from BMR4,6 cultivars; BMVs 5, 6a and 6b were common on BMR4,8 cultivars; BMV 5, 6b and 8 were common on cv. Regatta (BMR4,6a,7); BMVs 6a and 6b were common on BMR5,6c cultivars; and BMVs 6a, 6b and 8 were common on BMR10 cultivars. This may reflect the cultivation of groups of cultivars with overlapping combinations of resistance factors, as follows: BMR4,8-BMR4,6a-BMR4,6a,7-BMR4,6a,6b-BMR6b,6c-BMR5,6c; consequently, isolates which have virulence for several cultivars may have an advantage over those which have virulence matching only one cultivar. It may also reflect the presence of common clones of barley mildew which are adapted to one variety of barley, but also carry several unnecessary virulences.

The high frequency of isolates with the ability to infect a wide range of modern barley varieties are common indicates that the potential for effective variety diversification is, at the moment, limited. It also indicates a pressing need for more resistance genes to be introduced into barley breeding programmes and cultivated varieties.

Tests of single colony mildew isolates sampled from cultivars carrying BMR10a (M1-a13), including Digger, Koala, Pipkin and Sherpa, showed that all isolates which carried BMV10a (V-a13) had several unnecessary virulences. Single colony isolates were collected from leaf samples sent in by UKCPVS co-operators, and from seedlings exposed in the wind impaction spore trap (WIST) which was mounted on a car and driven on a number of routes in England and Scotland. Isolates were tested on the set of differential varieties shown in Table 5.

Table 5. Differential set of varieties used to identify virulences of isolates sampled from cultivars with BMR10a (M1-a13).

Variety	BMR group	Resistance gene	Variety	BMR group	Resistance gene
Golden Promise	0	-	Lofa Abed	4	M1-(La)
Rupal	10a	M1-a13	Hassan	5	M1-a12
W.37/136	1a	M1-h	Hordeum 1063	6a	M1-k
Igri	1b	M1-ra	Porter	6a	M1-a7
Julia	2a,2b	M1-g, M1-(CP)	Tyra	7	M1-a1
Midas	3	M1-a6	Simon	8,6a	M1-a9, M1-k

The virulences of 105 isolates have been determined. 86 of these isolates had, in addition to BMV10a, the four very common BMVs: 1a, 1b, 2a and 2b, and three unnecessary BMVs: 6a, 6b and 8; they lack BMVs 3, 4, 5 and 7. These isolates were sampled in Scotland, Wales, and a large area of England, and from all of the varieties listed in the previous paragraph. The next most common phenotype (13 isolates) was similar to that above, except that BMV8 was lacking. These isolates were sampled from the varieties Digger, Pipkin and Sherpa in Scotland, Lincolnshire, Cambridgeshire and Oxfordshire. Five isolates were similar to the most common type, except that they lacked BMV6b; all of these were from cv. Digger. One isolate was from Edinburgh, and four from Lancashire. One isolate, sampled from cv. Digger in Dyfed, had BMV5 and lacked BMV6b, but otherwise had the same virulences as the most common type.

The source of these isolates is, as yet, unknown. BMV8, carried by 92 of the 105 BMV10a isolates examined so far, is not a particularly common virulence gene in Britain. On the other hand, both BMV8 and BMV10a are common in several countries in continental Europe, including Denmark and Czechoslovakia; cultivars with either BMR8 or BMR10a have been grown in these two countries for some years. The possibility that a large part of the new population of BMV10a isolates is a clone, which has spread throughout Great Britain, can be tested using DNA polymorphisms. It may be rather harder to identify the ultimate source of the epidemic of mildew virulent on BMR10a cultivars, although a continental source is possible.

Survival of mildew on winter cultivars, most of which have no race-specific resistance, is a source of infection in the spring. The survival of isolates pathogenic on cv. Regatta during the winter 1987-1988 is shown in Table 6. Survival of such isolates on the winter crop allows the rapid development of epidemics in the spring.

Table 6. Pathogenicity on cv. Regatta, measured as colonies formed on cv. Regatta relative to the number formed on cv. Golden Promise, in mildew populations collected by exposing seedlings on a high roof in Cambridge.

Date collected	Pathogenicity on cv. Regatta
Autumn 1987	9
Winter 1987-1988	9
Spring 1988	8
Summer 1988	25
Autumn 1988	31

Tests using samples of barley mildew from Scotland suggest that Scottish populations are simpler and less diverse than those from England. Table 7 shows the differences in the levels of virulence for cvs. Triumph, Doublet, Klaxon, Natasha and Regatta. Cultivars, such as these, with complex resistance, are grown more widely in England than in Scotland.

Table 7. Geographical distribution of pathogenicity for some commercial spring barleys. Data are colony counts, relative to counts on cv. Golden Promise, on laboratory tested seedlings when inoculated with bulk isolates collected using the wind impaction spore trap (WIST) mounted on a car.

Location	Test cultivars				
	Triumph	Doublet	Klaxon	Natasha	Regatta
East Anglia	47	16	26	52	16
East Midlands	32	22	49	31	17
Northern England	27	9	36	16	40
Lothians	115	0	0	0	0
East Scotland	9	6	3	2	0
North Scotland	9	5	8	9	0

Pathogen response to fungicides

Following the decrease in resistance to triadimenol that was observed in 1987 (Wolfe et al, 1987), there appears to have been a reversal of this trend in 1988. Although in the East Midlands and Eastern Scotland, there was a reduction in the proportion of the population resistant to lower doses of triadimenol, there was an increase in other regions (Table 8). There was an increase in resistance to the field rate of triadimenol (0.375 g active ingredient/kg seed), however, in all regions.

Resistance to ethirimol increased in England and Northern Scotland from 1987 to 1988, but decreased in Eastern Scotland. There was no substantial change in the Lothians (Table 9).

Table 8. Geographical distribution of colony counts on seedlings of cv. Golden Promise treated with different rates of triadimenol, relative to counts on untreated seedlings. Seedlings were exposed in the WIST. Data for 1986-1988. ("-" = not tested).

Region	Rate of triadimenol in g active ingredient per kg					
	0.125			0.375		
	1986	1987	1988	1986	1987	1988
E. Anglia	45	32	41	44	17	27
E. Midlands	62	64	33	-	9	30
N. England	53	16	30	24	14	20
Lothians	59	37	45	24	6	43
E. Scotland	46	41	25	16	21	38
N. Scotland	71	35	76	39	28	72
Mean	56	38	42	29	16	38

Table 9. Geographical distribution of colony counts on seedlings of cv. Golden Promise treated with 1/15th of the field rate of ethirimol, relative to counts on untreated seedlings. Seedlings were exposed in the WIST. Data from 1986-88. ("-" = not tested).

Region	1986	1987	1988
E. Anglia	-	11	27
E. Midlands	-	23	46
N. England	31	15	20
Lothians	45	34	33
E. Scotland	78	63	23
N. Scotland	46	27	67

The figures in Table 10 show a variable response to morpholine fungicides in England and Scotland. There was little change in the level of resistance to tridemorph in East Anglia and the Midlands, a large rise in resistance in Northern England, the Lothians and Northern Scotland, and a decrease in resistance in Eastern Scotland. In all four of the northern areas, the figures for 1988 are similar to those for 1986. Figures for resistance to fenpropimorph were variable. Although there appears to have been a decrease in resistance in some regions, the trend towards increased resistance continued in the Lothians

Table 10. Geographical distribution of colony counts on seedlings of cv. Golden Promise treated with morpholine fungicides, relative to counts on untreated seedlings. Seedlings were exposed in the WIST. Data from 1986-88. ("-" = not tested).

Region	Tridemorph 1986	1987	1988	Fenpropimorph 1986	1987	1988
E. Anglia	-	27	26	-	11	0
E. Midlands	-	23	27	-	23	2
N. England	61	4	24	0	0	3
Lothians	50	7	43	3	6	19
E. Scotland	48	86	34	9	55	16
N. Scotland	96	47	94	2	22	75

Tridemorph as Bardew spray, 1/20 of field rate
Fenpropimorph as Corbel spray, 1/100 of field rate

and Northern Scotland. In all regions, there has been an increase in the level of resistance to fenpropimorph between 1986 and 1988. It should be noted that the doses of tridemorph and fenpropimorph used in these tests were very low. The results therefore show that isolates with low levels of resistance morpholines continue to be widespread.

Bulk isolates collected by exposing a tray of untreated seedlings in the WIST, and pooling spores from all colonies, were tested for resistance to fenpropimorph in the laboratory. Results are shown in Table 11. Although the small number of colonies from regions other than East Anglia makes comparisons difficult, there has been an increase in the frequency of bulk isolates with resistance to fenpropimorph since 1986 in all regions except Northern England and the Lothians.

Table 11. The number of bulk isolates tested and number (and fraction) of those isolates which were resistant to fenpropimorph, as Corbel (1/100 of commercial rate), in 1986, 1987 and 1988.

	1986 tested	1986 resis.		1987 tested	1987 resis.		1988 tested	1988 resis.	
East Anglia	29	0	(0.00)	14	4	(0.29)	43	4	(0.09)
East Midlands	6	0	(0.00)	2	0	(0.00)	7	1	(0.14)
Northern England	6	1	(0.17)	3	1	(0.33)	6	1	(0.17)
Lothians	4	1	(0.25)	3	2	(0.67)	2	0	(0.00)
Eastern Scotland	3	1	(0.33)	3	2	(0.67)	4	3	(0.75)
Northern Scotland	5	2	(0.40)	4	4	(1.00)	4	3	(0.75)

Single colony selections from bulk isolates collected in Scotland in 1987 and single colony isolates collected using the WIST in 1988 were analysed for resistance to triadimenol, ethirimol and fenpropimorph. Isolates with resistance to fenpropimorph can be divided into four groups according to their response to the three chemicals (Table 12). In 1986 all isolates with resistance to ethirimol and fenpropimorph had only medium resistance to triadimenol. The isolate in Group 4 in 1987 was the first to be identified with combined resistance to ethirimol, fenpropimorph and a high level of triadimenol. The number of isolates in this group increased in 1988. These

isolates may be selected by DMI/ethirimol and DMI/morpholine fungicide mixtures, and may pose a threat to efficient chemical control of barley mildew.

Table 12. The resistance to triadimenol, ethirimol and fenpropimorph of single colony isolates collected in Scotland and Northern England in 1986, 1987 and 1988.

Group	Chemicals to which isolates were resistant			Number of isolates		
	Triadimenol	Ethirimol	Fenpropimorph	1986	1987	1988
1	medium	-	+	0	5	2
2	medium	+	+	8	9	12
3	high	-	+	0	0	1
4	high	+	+	0	1	9

Chemical	Effective dose			
Triadimenol medium	1/15 field rate of Baytan			
Triadimenol high	field rate of Baytan			
Ethirimol	1/15 field rate of Milstem	)	+ =	resistant,
Fenpropimorph	1/100 field rate of Corbel	)	- =	sensitive.

References

J.K.M. Brown (1989) Ecological and Evolutionary Genetics of Erysiphe graminis DC. f. sp. hordei Marchal. Ph.D. Thesis, University of Cambridge.

E. Limpert (1987) Frequencies of virulence and fungicide resistance in the European barley mildew population in 1985. J. Phytopathology **119**, 298-311.

M.S. Wolfe, S.E. Slater and P.N. Minchin (1986) Mildew of barley. U.K. Cereal Pathogen Virulence Survey: 1985 Annual Report, 27-37.

M.S. Wolfe, S.E. Slater and P.N. Minchin (1987) Mildew of barley. U.K. Cereal Pathogen Virulence Survey: 1986 Annual Report, 26-33.

M.S. Wolfe, S.E. Slater and P.N. Minchin (1988) Mildew of barley. U.K. Cereal Pathogen Virulence Survey: 1987 Annual Report, 22-31.

MILDEW OF BARLEY IN NORTHERN IRELAND

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Although there was not a high incidence of mildew in 1988, 21 isolates were obtained, the bulk being from the 4 + 6a + b BMR group. Table 1 shows the cultivars used for examining the various virulences.

Table 1. Test cultivars for the detection of virulence groups

BMR group	Cultivar
0	Golden Promise
2	Zephyr
3	Midas
4	Varunda
5	Medallion
6a + b	Keg
6b + c	Triumph
7	Delta
8	Leith
3 + 4	Goldspear
4 + 5	Egmont
4 + 6a	Dram
4 + 6a + b	Klaxon
4 + 9	Atem

Table 2 shows the values for the mean pathogenicity of the isolates. Table 3 shows the values for corresponding pathogenicity from 1983 (with the exception of 1986 whose data are considered unreliable).

Table 2. Mean pathogenicity of bulk isolates in 1988 on test range of cultivars

BMR group	Isolate source	No	2	3	4	5	6a+b	6b+c	7	8	3+4	4+5	4+6a	4+6a+b	4+9
0	G Promise	2	69	7	42	30	77	36	27	152	8	101	49	40	15
1b	Igri	1	59	41	109	44	50	78	19	19	47	41	31	19	9
1b+2+3?	Torrent	1	13	8	18	54	46	29	21	42	8	19	4	43	1
2	Frolic	1	105	76	59	127	85	34	51	49	78	85	54	78	20
7	Delta	2	61	73	57	83	36	73	40	72	58	106	178	114	12
8	Chef	1	38	16	18	11	16	7	62	56	26	13	63	25	1
4+6a	Oboe	1	85	42	61	154	65	134	116	31	149	131	68	112	52
4+6a+b	Klaxon	7	55	35	35	81	74	84	18	61	39	54	64	76	33
4+6a+b	Escort	1	35	1	1	60	67	29	25	3	20	24	79	64	20
4+6a+b	Joanna	1	49	0	44	109	47	100	87	16	103	49	69	61	41
4+7	Vista	1	55	6	12	87	38	46	35	52	11	84	30	12	20
?	Camac	1	93	41	50	106	72	11	75	15	6	23	57	67	18
?	Kestrel	1	37	42	15	45	86	25	32	25	13	1	24	35	10

Table 3. Non-corresponding pathogenicity values in Northern Ireland from 1983-1985 and from 1987-1988

	BMV Characters									
Year	2	3	4	5	6a+b	6b+c	3+4	4+5	4+6a+b	4+9
1983	59	53	59	37	16	22	45	32	-	-
1984	48	45	42	40	17	24	29	38	-	-
1985	65	54	60	69	31	37	35	34	-	-
1987	92	28	63	31	39	33	12	61	30	5
1988	57	33	50	76	54	66	46	65	59	24

Over this time values for BMV groups 2 and 4 have remained fairly steady, while BMV group 3 has declined. The latter decline corresponds with one in England over the same period (Wolfe, Slater and Minchin, 1987). The combined virulences have generally increased. Groups 4 + 6a + b and 4 + 9, which were only measured since 1987 have both shown big increases. This reflects the popularity of Klaxon and Atem, particularly the former which has generally had a fairly high incidence of mildew in the field. This has not been the case so far for Atem which has been very clean, but it indicates possible trouble in the coming season.

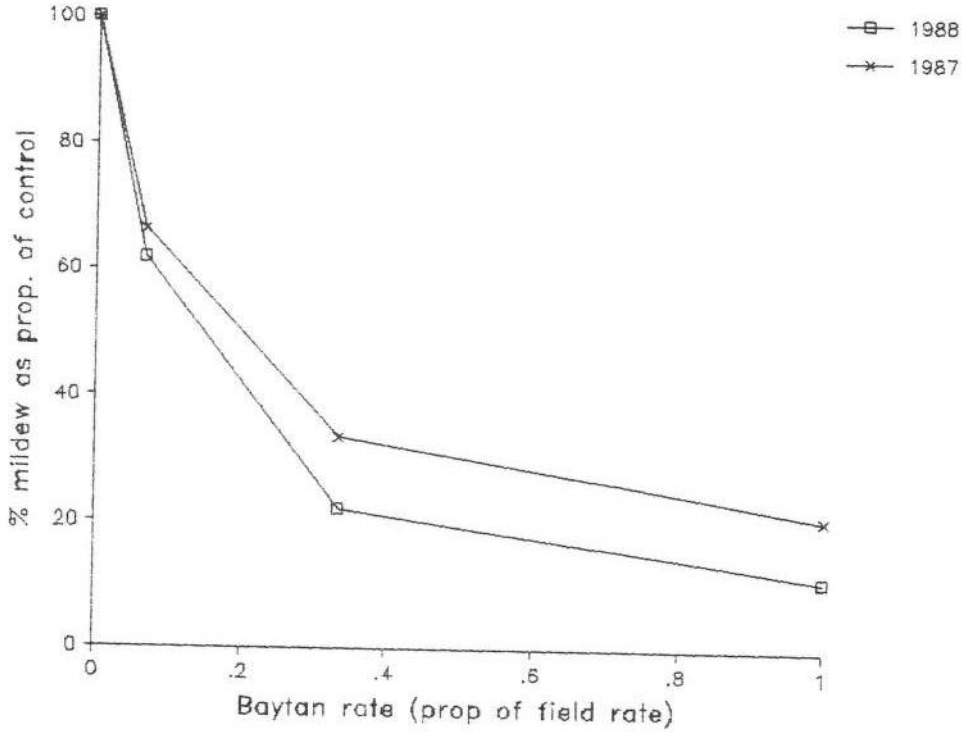

Fig 1. Percentage of colonies of mildew growing on Baytan-treated seedlings as a proportion of those on untreated seedlings (100%).

In 1988 tests were performed with various rates of Baytan seed-dressing, as in 1987, to see if there were any indications of resistance. Results are shown graphically in Fig 1 and are compared with from 1987 (there was clearly an error in the results reported in 1987 and data have been corrected). In both years there is a fairly smooth response to the dosage rate and although there is not a complete lack of growth at the full field rate there is no indication of any increase over the two years. If anything it is the reverse.

REFERENCE

Wolfe, M.S., Slater, S.E. and Minchin, P.N. (1988). Mildew of barley. United Kingdom Cereal Pathogen Virulence Survey Annual Report. 22-28.

BROWN RUST OF BARLEY

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Isolates from 60 of the 217 samples of barley brown rust received in 1988 were tested on seedlings of the differential cultivars. No new virulences or virulence combinations were detected, race octal 1653 being predominant. In field isolation nurseries, winter barley cultivars displayed a range of quantitative responses to races octal 1673 and 677. These cultivar differences appeared to be of a race non-specific nature, cultivar rankings between isolates remaining constant. Within spring cultivars, interpretation of field data was difficult due to the contamination of race octal 677 with race octal 1673. Results did however enable several new spring barley cultivars to be placed in BBR-groups. Cv. Delphine was placed in Group IV with cv. Simon (BBR-3) and cv. Fergie in Group V with cv. Corniche (BBR-10+?).

GLASSHOUSE SEEDLING TESTS WITH 1988 ISOLATES

Two hundred and seventeen samples of barley brown rust were received. This number included 50 samples sent from the MAFF cereal survey specifically for fungicide insensitivity screening at the East of Scotland College of Agriculture (Dr J. Gilmour, H-GCA - funded project). Two hundred and nine of the samples originated from a wide range of winter barley cultivars, only 4 samples being received from spring barley cultivars. The large number of samples prevented the culture and testing of each one, thus samples were selected on the basis of their diverse cultivar and geographical origin. The 60 isolates thus cultured were tested on the standard set of ten differential cultivars (Table 1) together with cv. Corniche which has shown high levels of resistance in previous years' isolation nurseries.

Table 1. Barley genotypes used to identify virulence factors in *Puccinia hordei* and their ranking for octal notation

Cultivar	BBR factor	Gene symbol	Ranking for octal notation
Sudan	1	Pa	1
Peruvian	2	Pa_2	2
Ribari	3	Pa_3	3
Gold	4	Pa_4	4
Quinn	5	Pa_5	5
Bolivia	6	Pa_6	6
Cebada Capa	7	Pa_7	7
Egypt 4	8	Pa_8	8
CI 1243	9	Pa_9	9
Triumph	10	Pa?	10

Group I cultivars, Midas and Golden Promise, are 'universal susceptibles'. Cultivars previously (Jones, 1987) classified as BBR-10 carriers include Triumph, Prisma, Doublet, Natasha, Blenheim, Klaxon and Regatta. These cultivars were again resistant to race 11 but confirmation of their resistance to race octal 677 could not be made as contamination with BRV-10 carriers rendered them susceptible. Cvs Joline and Armelle gave a hypersensitive response to race octal 11 and gave low levels of infection in the other two nurseries. New cultivars that followed this general pattern and which are thus tentatively placed in Group II are cvs Montana, Hart and Oboe.

Group III cultivars carry the quantitatively expressed non-specific resistance BRR-V derived from Hordeum laevigatum and exemplified by cv. Vada: the new cv. Brenin is provisionally placed in this group.

Group IV is assigned to cultivars carrying BBR-3 (gene Pa_3) and cv. Simon is the type-cultivar for this group. Of the three isolates tested, only race 677 carries BRV-3 and this clearly differentiated cv. Simon and the new cv. Delphine from all others tested. To complete the analysis, the resistance to Triumph-virulence of cv. Corniche in the adult plant stage was confirmed. The only other cultivar tested that was highly resistant to all three isolates i.e. all known virulence factors, was the newly included cv. Fergie.

REFERENCES

JONES, E.R.L. (1988). Brown rust of barley. UK Cereal Pathogen Virulence Survey for 1987 Annual Report. pp. 34-38.

Results

The virulence combinations identified and their frequencies are given in Table 2. No new virulences or virulence combinations were identified from the isolates tested in 1988.

Table 2. Races identified from 1988 isolates

Number of isolates (frequency)	Octal designation	BRV factor
34 (0.57)	1653	1,2,4,6,8,9,10
16 (0.27)	1673	1,2,4,5,6,8,9,10
10 (0.16)	673	1,2,4,5,6,8,9

Virulence to the differential cv. Ribari (BBR-3) was not detected. Seedlings of cv. Corniche displayed a pattern of response similar to that of cv. Triumph to all isolates tested confirming the 1987 results. However, additional field data suggest that the cultivar also possesses resistance which is expressed at the adult plant stage of growth which is not possessed by cv. Truimph.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Thirty-two winter and 24 spring barley cultivars were sown in each of two nurseries. One was inoculated with race octal 1673 and the other with race octal 677. A third nursery was sown with spring cultivars only and inoculated with the simple race octal 11.

Race Octal	BRV-factors
1673	1,2,4,5,6,8,9,10
677	1,2,3,4,5,6,8,9,
11	1,4

Results

Reasonably high levels of infection developed on the susceptible cultivars within each of the nurseries by the end of the season. The winter barley cultivars gave compatible reactions with races octal 1673 and 677. Cultivars varied in their quantitative responses to infection although, overall, a higher level of infection was achieved in the race 677 nursery. Cv. Gaulois was the most susceptible to both isolates, the remainder displaying a similar pattern of decreasing susceptibility within both nurseries (Table 3).

Levels of infection within the spring barleys were generally highest in the nursery inoculated with race octal 11. The nursery inoculated with race octal 677 appears to have become contaminated with Triumph-virulent pathotypes early in the season which makes interpretation of the results difficult. Nevertheless, using the current and previous years' data, cultivars were placed into resistance groups (Table 4).

Table 3. Percentage infection* of winter barley cultivars with specific isolates of P. hordei Otth. in field isolation nurseries in 1988

Winter cultivar (NIAB rating)	Isolates: Race Octal 1673 BRV-1,2,4,5,6,8,9,10	Isolates: Race Octal 677 BRV-1,2,3,4,5,6,8,9
Gaulois (8)	31	44
Calix	29	41
Posaune (5)	27	39
Cashmir	27	34
Plaisant	25	45
Mimosa (4)	25	40
Melusine (5)	25	38
Pirate (5)	24	43
Marinka (5)	24	34
Panda (6)	24	38
Carrera	23	34
Waveney (3)	23	32
Igri (5)	23	31
Gerbel (4)	21	43
Masto (4)	20	34
Target	19	29
Kaskade	19	36
Kira (5)	17	33
Pastoral (6)	17	26
Finesse (6)	16	27
Pipkin (4)	16	26
Vixen (5)	15	27
Torrent (4)	15	26
Sonate	15	25
Halycon (5)	15	24
Nevada	15	22
Koala	14	28
Concert	13	29
Otter	13	24
Frolic (5)	13	21
Magie (5)	12	26
Puffin (8)	8	22

*Mean of 4 replicates at 3 assessment dates.
All reaction types susceptible.
( ) NIAB rating: 1 = Susceptible, 9 = Resistant.

Table 4. Reactions* of spring barley cultivars to specific isolates of P. hordei Otth. in field isolation nurseries in 1988

Spring cultivar (NIAB rating)	Isolates Race Octal 1673 BRV-1,2,3,4,5,6,8,9,10	Race Octal 677 BRV-1,2,3,4,5,6,8,9	Race Octal 11 BRV-1,4
Group I (BBR-0)			
Midas	29	30	47
Golden Promise	29	29	39
Group II (BBR-10)			
Triumph (5)	10	9	2MS
Prisma (5)	16	17MS	1
Doublet (6)	17	10	5MR
Natasha (5)	19	6	2MR
Blenheim (4)	21	15MS	6MR
Regatta (7)	16	11	6MR
Klaxon (7)	14	10	10MR
Joline (8)	9	7MS	3R
Armelle	13	8	2MR
Montana	19	18	16MR
Hart (4)	14	16	15MR
Oboe	2MS	5MS	4MR
Group III (BBR-V)			
Vada	6MS	4MS	17
Atem (4)	24	19	35
Digger (5)	14	15	18
Cameo	17	10MS	29
Kym	16	10MS	24
Brenin	16MS	15MS	30
Group IV (BBR-3)			
Simon	0.1MR	10	3R
Delphine	0.5R	8MS	2R
Group V (BBR-10+?)			
Corniche (9)	1	2MR	0
Fergie	0.5MS	0.5MR	0.5R

*Percent infection: mean of 4 replicates at 2 assessment dates
All reaction types susceptible unless stated
MS = Mixed susceptible; MR = Mixed resistant, R = Resistant
( ) NIAB rating: 1 = Susceptible, 9 = Resistant

BROWN RUST OF BARLEY : FUNGICIDE SENSITIVITY (HGCA-sponsored project)

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The sensitivities of isolates of barley brown rust, collected during 1987, to triadimefon and propiconazole were determined (EC50s) in tests with detached leaf segments and compared with those of some isolates collected before 1987. Preliminary results have been published (Boyle et al, 1988) and are summarised here.

There was a 23-fold difference of sensitivity to triadimefon between the most sensitive and the least sensitive isolates, although most fell within an eight-fold range. There was a 10-fold range of sensitivity to propiconazole among the smaller number of isolates tested. Some isolates showed broadly similar sensitivity to both fungicides while others were more sensitive to one fungicide than the other. The earlier isolates were among the most sensitive to propiconazole but not to triadimefon. There was no apparent relationship between fungicide sensitivity and virulence in the small sample so far tested. Pustule production of some isolates was stimulated at the lowest fungicide concentrations.

REFERENCE

BOYLE F, GILMOUR J, LENNARD J H, CLIFFORD B C and JONES E R L (1988) Sensitivity of cereal brown rust fungi to triadimefon and propiconazole. Brighton Crop Protection Conference - Pests and Diseases - 1988, 1, 379-384.

RHYNCHOSPORIUM OF BARLEY

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Virulence combinations were identified from the 48 isolates of Rhynchosporium secalis tested on seedlings in 1988. All samples were from winter barleys. The spring barley cv. Joline was shown to carry BBR-1, also present in cv. Armelle. Cvs La Mesita (BBR-5), Osiris (BBR-6), and Digger (BBR-?) were resistant to all isolates. Low levels of infection within field isolation nurseries made results difficult to interpret. The winter barley cvs Posaune and Panda may carry specific resistances, virulence to which is carried by race octal 77. The majority of isolates came from Rosemaund, Herefordshire and St. Clears, Dyfed. No new virulences or virulence combinations were detected.

SEEDLING TESTS WITH 1988 ISOLATES

Although 64 of the 78 samples of barley leaf blotch received in 1988 were from two trial sites, namely Rosemaund, Herefordshire and St. Clears, Dyfed (Table 1), the samples came from a wide range of winter barley cultivars. No samples were received from spring barley cultivars.

Table 1. Geographic origin of Rhynchosporium samples received in 1988.

Geographic origin	Number of samples
ENGLAND (ADAS region)	
West-Central	31
East-Central	6
East	5
WALES	35
SCOTLAND	1
Total:	78

Forty-eight isolates were successfully increased and tested on a set of differential cultivars as well as additional winter and spring cultivars. Test cultivars and their resistance factors are given in Table 2.

Table 2. Differential test cultivars for Rhynchosporium secalis.

Resistant factor	Cultivar	Octal rank
BRR-0	Maris Mink	-
BRR-1	Armelle	1
BBR-2	Astrix	2
BRR-3	Athene	3
BRR-4	Igri	4
BRR-5	La Mesita	5
BRR-6	Osiris	6
BRR-7	Pirate	7

Results

When classified by their reactions on the standard set of differential cultivars, the isolates successfully tested gave a range of different known virulence combinations. Each virulence combination identified (Table 3) has been designated by an octal virulence number (Jones & Clifford, 1984).

Table 3. Virulence factor combinations identified from the 1988 survey

No. of isolates	Differential cultivar reaction*							Oct. vir. des.
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
30	1	0	0	1	1	0	0	114
8	0	0	0	1	1	0	0	14
9	1	0	0	1	1	1	1	117
1	0	0	0	0	0	0	0	0
Virulence frequency								
1988	0.81	0	0	0.98	0.98	0.19	0.19	
1987	0.46	0	0	0.59	0.75	0.16	0.16	

*1 = Susceptible, 0 = Resistant

Virulence to cv. Pirate was found at an increased frequency of 0.81, a sharp increase from the 0.46 observed in 1987. The spring barley cv. Joline, which showed specific resistance in the 1987 isolation nurseries, gave an identical pattern of response to the isolates tested as cv. Armelle, suggesting that it too carries BRR-1. Cvs La Mesita and Osiris were resistant to all isolates, although virulence to these had been detected in previous years.

The winter barley cvs Gerbel and Hoppel again showed low levels of infection to the isolates.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Two nurseries comprising 35 winter and 26 spring barley cultivars were sown in the 1987-88 season and each was inoculated with one of the following isolates.

Isolates used in field tests in 1988

UK CPVS Code	Virulence characteristics	Octal designation
Rs-85-50	BRV-1,2,3,4,5,6	77
Rs-88-78	BRV-0	0

The nursery inoculated with isolate Rs-88-78 was grown alongside a Rhynchosporium disease nursery used to screen breeding material and which is infected naturally annually. Leaf samples taken from the nursery during the season and subsequently tested on seedlings of the standard set of differential cultivars identified the isolate, Rs-88-78, as race octal 0, although low levels of infection (5-10%) were recorded on cvs Athene, Igri and Pirate.

Results

The results are summarised in Table 4 (winter cultivars) and Table 5 (spring cultivars). Higher levels of infection were recorded on the susceptible cultivars within the nursery inoculated with isolate Rs-88-78. This may have been due to additional inoculum spreading from the adjoining heavily infected screening nursery, and also because the location of the nursery was particularly conducive to disease development. To facilitate comparisons in levels of infection on individual cultivars between nurseries, percentage levels of infection were adjusted relative to cv. Otter, (set at 100%).

Quantitative differences were apparent between winter cultivars within individual nurseries reflecting differences in susceptibility of the cultivars. Cultivar Pipkin (BRR-5) was more heavily infected within the nursery inoculated with isolate octal 0, which does not carry the corresponding virulence factor (BRV-5), than it was when inoculated with the isolate carrying BRV-5. Although cv. Pipkin, like cv. La Mesita from which it derives its resistance, is more susceptible at the adult plant stage of growth (Clifford & Jones, 1982) there is no explanation as to why it should be more susceptible to an isolate not carrying the corresponding virulence factor. The higher levels of disease within this nursery may have induced higher susceptibility. Other cultivars to have shown greater susceptibility to the simpler isolate included Vixen, Kira, Plaisant and Pirate. By contrast, cvs Panda, Posaune and Athene displayed much higher levels of infection within the nursery inoculated with isolate (Rs-85-50 which carries virulence to the specific resistance of cv. Athene (BRR-3). No disease developed within the spring barley nursery inoculated with octal race 77. This was due to spray damage during the very dry weather of May. Low levels of infection did develop within the spring cultivars inoculated with race octal 0 (Table 5): cvs Armelle(BRR-1), Joline (BRR-1), Osiris (BRR-6), Corgi (BRR-5), La Mesita (BRR-5) and Digger (BRR-?) were all highly resistant to this isolate which does not carry the corresponding virulence genes.

REFERENCES

JONES, E.R.L. & CLIFFORD, B.C. (1984). Rhynchosporium of Barley. UK Cereal Pathogen Virulence Survey 1983 Annual Report. pp. 60-63.

Table 4. Percent infection* relative to Maris Otter of winter barley cultivars in Rhynchosporium isolation nurseries, 1988

Cultivar	Isolate Rs-85-50 BRV-1,2,3,4,5,6	Rs-88-78 BRV-0
Otter	100 (28)	100 (43)
Pipkin	46	100
Vixen	43	95
Kira	29	63
Puffin	54	58
Sonate	71	54
Cashmir	32	51
Finesse	32	51
Igri	29	49
Magie	29	47
Plaisant	11	47
Panda	82	40
Calix	36	37
Kaskade	18	33
Posaune	79	30
Gaulois	21	28
Pirate	11	28
Carrera	21	28
Pastoral	36	28
Halycon	18	26
Athene	50	21
Melusine	29	19
Frolic	25	16
Nevada	25	16
Koala	18	16
Gerbel	11	16
Concert	25	14
Masto	18	14
Waveney	14	14
Mimosa	14	14
Target	11	14
Astrix	7	12
Torrent	11	9
Marinka	2	7
Hoppel	7	5

*Mean of 2 scoring dates, 4 replicates
( ) actual % leaf area infected
Leaf area infected on cv. Otter inoculated with isolate Rs-88-78 on:
1st scoring date = 35%
2nd scoring date = 50%

Table 5. Percent infection* of spring barley cultivars in Rhynchosporium isolation nurseries, 1988

Cultivar	Isolate Rs-88-78 BRV-0
Delphine	7
Brenin	7
Prisma	6
Montana	6
Hart	6
Atem	6
Corniche	3
Blenheim	3
Fergie	3
Oboe	2
Midas	2
Doublet	2
Proctor	2
Cameo	2
Natasha	2
Golden Promise	1
Klaxon	1
Regatta	1
Kym	1
Triumph	1
Joline	1
Corgi	1
Digger	0.5
Osiris	0
Armelle	0
La Mesita	0

*Mean of 4 replicates, 1 scoring date

NET BLOTCH OF BARLEY

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From the twenty samples of net blotch received in 1988, 18 isolates were successfully tested on the differential cultivars. In general, these isolates were more widely virulent than those from previous years. Although sample numbers were small, cautious interpretation of virulence frequencies detected since 1983 suggests that some differential cultivars can be grouped on the basis of similar patterns of response, with the implication that they carry common resistance factors. These groupings include 1) CI 5401 and CI 9820 2) CI 6311, CI 1243 and CI 4979, 3) CI 4795, CI 4502 and CI 9214. A high frequency of virulence was again detected for cv. Marinka although it continues to occupy a small acreage, further evidence of the apparently non host directed variation in the pathogen. The susceptibility of cv. Marinka was confirmed in adult plant field tests, where the newly introduced cvs Puffin, Koala, Gaulois and Target were also susceptible to a netting isolate. Effective field resistance is common in current winter barleys.

GLASSHOUSE SEEDLING TESTS WITH 1988 ISOLATES

Twenty samples of net blotch were received in 1988 from winter barley cultivars grown on farms and in trials at different locations in England and Wales (Table 1).

Table 1. Cultivar and geographic location of 1988 net blotch samples

Location	Sample number	Cultivar
Little Clacton, Essex	UK 88/1	Torrent
" " "	UK 88/2	B 15
" " "	UK 88/3	B 101
Lexham Estate, Norfolk	UK 88/4	Marinka
Cockle Park EHF, Northumberland	UK 88/5	Puffin
" " "	UK 88/6	Torrent
" " "	UK 88/7	Panda
" " "	UK 88/8	Gerbel
" " "	UK 88/9	Plaisant
" " "	UK 88/10	Melusine
" " "	UK 88/11	Target
" " "	UK 88/12	Concert
" " "	UK 88/13	Gaulois
" " "	UK 88/14	Pirate
" " "	UK 88/15	Igri
Rosemaund EHF, Hereford	UK 88/16	Marinka
Bridgend, Mid-Glamorgan	UK 88/17	Marinka
	UK 88/18	?
	UK 88/19	?
	UK 88/20	?

The isolates of Pyrenophora teres successfully cultured were inoculated onto seedlings of 13 differentials together with cvs Marinka and Triumph (Table 2) using procedures described previously (Clifford & Jones, 1981).

Table 2. Differential cultivars used for virulence testing

Code Number	W.P.B.S. Accession number	Cultivar Type
1	Cb 1613	CI 5401 Spring
2	Cb 1615	CI 6311 Spring
3	Cb 1619	CI 9820 Spring
4	Cb 1593	CI 739 Spring
5	Cb 1595	CI 1243 Spring
6	Cb 1606	CI 4795 Spring
7	Cb 1605	CI 4502 Spring
8	Cb 1611	CB 4979 Spring
9	Cb 763	Proctor Spring
10	Cb 3661	Code 65 Winter
11	Cb 3662	CI 9518 Winter
12	Cb 3663	Tenn 61-119 Winter
13	-	CI 9214 Spring
14	-	Marinka Winter
15	-	Triumph Spring

Results

Viable cultures were isolated from 18 of the 20 samples received and were successfully tested on the differential cultivars. In interpreting the results, it must be emphasised that the number of isolates available is limited and these were obtained from only five sites, albeit geographically diverse. Overall, the isolates were more widely virulent than those obtained in previous years and this did not relate to specific virulence for any particular differential cultivar. The individual virulence frequencies, and those for the previous five years are given in Table 3.

Table 3. Frequencies (%) corresponding to each differential cultivar (UK CPV Surveys 1983-1988)

Code Number	Cultivar	1983	1984	1985	1986	1987	1988
1	C.I. 5401	0	0	14*	0	0	28
2	C.I. 6311	0	22	21	39	0	72
3	C.I. 9820	0	0	56*	4	0	28
4	C.I. 739	24	33	33	61	20	50
5	C.I. 1243	0	44	42	57	0	39
6	C.I. 4795	0	0	0	0	10	33
7	C.I. 4502	0	0	0	0	0	33
8	C.I. 4979	0	44	33	50	0	56
9	Proctor	52	55	90	79	30	56
10	Code 65 (W)	19	0	7	0	0	72
11	C.I. 9518 (W)	90	100	90	96	90	39
12	Tenn. 61-119 (W)	19	44	33	57	60	89
13	C.I. 9214	9	0	0	0	0	56
14	Marinka	-	-	-	0	79	67
No. of isolates tested		21	9	15	28	24	18

(W) = Winter cv.; *'spotting' isolates

Although fluctuations in virulences were generally towards an increase, that for CI 9518 showed a decline to 39% from at least 90% in 1987 and previous years. In 1985, CI 5401 and CI 9820 were only susceptible to spotting isolates whereas, in all other years, neither line expressed susceptibility except in 1986 when a very low frequency was observed on CI 9820. In 1988, an increase in virulence frequency was evident to 28% of isolates on both lines. These observations indicate that the corresponding virulences to these lines tend to vary together. Similar trends occur for the cvs CI 6311, CI 1243 and CI 4979. Virulence for these was not detected in 1983 and 1987 but relatively high frequencies were observed in the intervening years and again in 1988.

Other virulences observed to have higher frequencies in 1988 were those for CI 4795 and CI 4502 and once again these two appear to vary together, both being at 0% in all previous years except 1987 when a low frequency was observed on CI 4795. A third cultivar that shows similar variation is CI 9214.

Possible explanations for these correlated responses are either that the specific virulences are associated in the pathogen or that the cultivars carry a common resistance factor (s). Clearly, a genetic analysis of the differential cultivars to determine the inheritance of resistance factors is called for.

A further confusion relates to the differences in virulence frequencies between the purported common resistance carriers within one year e.g. cvs CI 5401 and CI 9820 in 1985. This may be because classification between resistance and susceptibility for a particular isolate/cultivar interaction is not clear-cut and may be influenced by environmental conditions, inoculum density etc. In addition, there may be minor genetic factors in either the host or pathogen that modify the outcome of a specific interaction.

The results cannot be explained simply by biased sampling as, although relatively few samples are received, they are from a range of cultivarsfrom widely differing locations. For example, in 1988, samples came from Northumberland, Essex, Mid-Glamorgan, Hereford and Norfolk.

It is also interesting to examine the data on cv. Marinka. Virulence was first detected in 1987 in 79% of the isolates and yet the cultivar occupied an insignificant proportion (ca 5%) of the winter barley acreage. In 1988, the frequency was 67% while the acreage remained at ca 10%. Together with the data presented above, this seems to indicate that virulence frequencies within P. teres populations fluctuate somewhat randomly from year to year.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Thirty-two winter and 24 spring cultivars were sown in each of two nurseries in 1987-1988, one inoculated with isolate BNS-87-24 which was virulent on cv. Marinka in seedling tests in 1987, and the other with the cv. Marinka avirulent isolate BNS-85-45.

Isolate	Virulence combinations
BNS-87-24	4,9,11,12 (Netting form)
BNS-85-45	3,4,9,11 (Spotting form)

Results

In the abnormally dry spring and early summer, disease was slow to build up within the winter cultivars inoculated with the netting isolate BNS-87-24, but sufficient infection towards the end of the season enabled one disease assessment to be made (Table 4). Negligible levels of disease developed in the winter nursery inoculated with the spotting isolate BNS-85-45 or in either of the spring nurseries, rendering assessment impossible.

The winter barley cultivars displayed a range of quantitative responses from the most susceptible cv. Concert (10%) to cvs Maris Otter (0.3%)and Cashmir (0%) which were highly resistant. The new cultivars under test, Puffin, Koala, Gaulois and Target, fell within the more susceptible group and cv. Marinka which was previously highly resistant (NIAB rating 9) was susceptible confirming the observation in 1987 seedling tests of widespread virulence (Jones & Clifford, 1988).

Table 4. Percentage infection* on winter barley cultivars inoculated with Pyrenophora teres in a field nursery in 1988

Cultivar (NIAB rating)	Netting form BNS-87-24 (4,9,11,12)
Concert	10
Panda (6)	10
Puffin (4)	10
Koala	10
Gaulois (6)	8
Target	6
Masto (7)	6
Nevada	5
Marinka (9)	5
Halycon (8)	5
Melusine (7)	5
Sonate	5
Kaskade	5
Magie (9)	4
Frolic (8)	4
Finesse (7)	4
Posaune (5)	4
Gerbel (6)	3
Pastoral (6)	3
Waveney (6)	3
Torrent (8)	3
Plaisant	2
Igri (5)	2
Mimosa (9)	2
Carrera	2
Vixen (9)	2
Calix	2
Pipkin (8)	1
Kira (8)	1
Pirate (7)	1
Maris Otter	0.3
Cashmir	0

*Mean of 4 replicates, 1 assessment date

The pathogen, or more precisely, the host:pathogen interaction, continues to display a perplexing and unpredictable degree of variability. This is shown both by the difficulty in establishing adequate levels of disease in field nurseries despite the input of considerable technical expertise, and also in the variation in specific interactions between pathogen and host when tested at the seedling stage under defined and controlled conditions. Some of this unpredictable variation may have its basis in the heterokaryotic nature of the pathogen; the occurrence of two symptom-morhpological forms, Pyrenophora teres f. teres and P.t. f. maculata producing netting and spotting lesions respectively, adds to this complexity which helps to confuse rather than clarify the unpredictable epidemiology. The pathosystem would clearly reward further study. In the 1988-1989 season different inoculation procedures are being adopted to try and ensure development of net blotch within the nurseries.

REFERENCES

Clifford, B.C. and Jones, D. (1981). Net blotch of barley. UK Cereal Pathogen Virulence Survey 1989 Annual Report, pp. 71-77.

Jones, E.R.L. and Clifford, B.C. (1988). Net blotch of barley. UK Cereal Pathogen Virulence Survey 1987 Annual Report, pp. 44-46.

MILDEW RESISTANCE OF THE NET BLOTCH DIFFERENTIALS

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The net blotch differential cultivars were tested with a range of mildew isolates (Table 1).

Table 1. Number of colonies on detached leaf segments of the Net Blotch differentials after inoculation with a range of mildew test isolates

	Test isolate number, CC/-										BMR
	133	128	124	59	58	99	82	38	16	32	grp
CI 4502	393	265	214	686	158	234	216	267	184	99	0/1b
CI 1243	0	0	0	0	0	0	0				Res
Proctor	279	150	80	343	73	116	118	127	134	81	0
CI 5401	179	115	148	510	119	143	120	225	213	115	0/1b
Code 65	100	42	4	481	27	93	0				6(2)?
CI 4979	0	0	51	157	0	0	0	208	133	0	7(1b)
CI 4795	307	219	175	238	135	179	195	305	112	143	0/1b
CI 9214	229	131	98	252	46	170	111	257	95	59	0/1b
CI 9518	129	0	6	71	12	43	1				6b/c
CI 6311	0	0	6	67	0	7	0				6c,7
CI 9820	7	0	0	0	0	2	8				Res
CI 739	314	231	151	624	158	255	202	225	203	167	0/1b
Tenn 61	0	0	10	0	0	0	0				Res
Midas	71	150	118	0	0	0	0				
Lofa	0	12	112	29	88	89	101				
Hassan	21	150	27	33	0	71	109				
H.1063	300	231	123	410	81	5	109				
Porter	250	88	7	233	73	87	10				
Triumph	107	19	0	157	8	100	0				
Digger	236	65	0	0	0	0	0				
Pipkin	64	162	0	14	0	0	0				
Simon	0	0	118	0	0	0	99				
GP	100	100	100	100	100	100	100	100	100	100	
BMV group of the test isolates											
	1	1	1	1	1	1	1	1	1	1	
	2	2	2	2	2	2	2	2		2	
	3	3	3						3	3	
			4		4	4	4		4		
		5				5	5	5			
	6a	6a	6a	6a	6a		6a				
	6b	6b		6b	6b	6b					
	6c			6c		6c					
			7	7				7	7		
			8				8				
	10a	10a									
	10b	10b									

There does not appear to be any relationship between the mildew resistances and net blotch resistances carried by the differential cultivars (Table 2)

Table 2. Virulence frequencies (%) (net blotch) corresponding to each differential cultivar (UKCPV Surveys 1983-1988)

Cultivar	(BMR Group)	1983	1984	1985	1986	1987	1988
CI 4795	(0/1b)	0	0	0	0	10	33
CI 4502	(0/1b)	0	0	0	0	0	33
CI 9214	(0/1b)	9	0	0	0	0	56
CI 5401	(0/1b)	0	0	14*	0	0	28
CI 9820	(Res)	0	0	56*	4	0	28
CI 6311	(6c/7)	0	22	21	39	0	72
CI 1243	(Res)	0	44	42	57	0	39
CI 4979	(7/1b)	0	44	33	50	0	56
Code 65	(6(2)?) (w)	19	0	7	0	0	72
CI 9518	(6b/c) (w)	90	100	90	96	90	39
CI 739	(0/1b)	24	33	33	61	20	50
Tenn 61.119	(Res) (w)	19	44	33	57	60	89
Proctor (0)		52	55	90	79	30	56

(w) = Winter cv; * = 'Spotting' isolates

MILDEW OF OATS

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Forty-four samples were received and from these, 34 isolates were successfully cultured. The results confirmed the trend in recent years of the relatively complex race 5 (OMV 1,2,3) being predominate. This race is able to attack all commercial oat cultivars. The only other virulence combination detected in 1988 was OMV 1,2 (race 3).

SEEDLING TESTS WITH 1988 ISOLATES

A total of 44 samples of Erysiphe graminis avenae was received in 1988 of which 25 were from winter, 18 from spring oat cultivars and one of unknown origin. The 28 samples received from England were from the following ADAS regions: 13 from the East, 8 from East-Central and 7 from West-Central. Nine samples were received from Wales, 6 from Eire and 1 from Scotland. Isolates were successfully cultured from 34 of the samples, and tested on a set of differential cultivars.

Results

The geographical origins of the mildew samples tested, together with their virulence factors, are given in Table 1. The frequency of occurrence of the various virulences detected in 1988, together with those for the previous ten are given in Table 2. The relatively complex OMV 1,2,3 (race 5) predominated (68%), as in the previous four years. These virulence factors enable it to attack all cultivars on the current NIAB Recommended List of winter and spring oats. The only other virulence combination identified from the 1988 samples was OMV 1,2 (race 3). This simpler race which occurred in 32% of the samples , is unable to infect cultivars such as Avalanche and Rollo which carry OMR-3.

Races 2 (OMV 1) and 4 (OMV 1,3) have not been detected in isolates tested since 1983 and 1984 respectively. Virulence to the A. barbata (OMR-4) resistance was not detected, although the majority of isolates gave 1-2 type pustules when inoculated onto the differential Cc 6490 (OMR-4). This resistance is not present in any of the cultivars being grown commercially within the UK.

Table 1. Locations and cultivars from which viable mildew samples were received with virulences identified for each sample

Location	Cultivars	Virulences (OMV)
ENGLAND		
East		
Morley, Norfolk	Image, Peniarth, Lustre, Solva, Pennal	1,2
	Aintree	1,2,3
I.P.S.R., Cambridge	Commander, Major, Rollo	1,2,3
East-Central		
Headley-Hall, N. Yorkshire	Lustre, Solva, Major, Peniarth	1,2
	Aintree, Image, Dula, Pennal	1,2,3
West-Central		
Rosemaund, Herefordshire	Lustre, Peniarth, Solva, Image	1,2,3
WALES		
Trawscoed, Dyfed	Semn 581/1	1,2
	Avalanche, Dula, Rollo, Keeper, Major, Wilma	1,2,3
W.P.B.S., Dyfed	Breeding Line	1,2,3
EIRE		
Leixlip, Co. Kildare	Image	1,2
	Aintree, Pennal, Major	1,2,3
SCOTLAND		
Dundee	Dula	1,2,3

Table 2. Virulence group frequencies identified from samples received in 1988 compared with years since 1978

Virulence		Frequency (% total)						No. of isolates
Group	Race	1978	1980	1982	1984	1986	1988	in 1988
OMV 1	2	3	0	0	0	0	0	0
1,2	3	42	51	39	32	31	32	11
1,3	4	3	3	4	2	0	0	0
1,2,3	5	52	41	43	64	63	68	24
1,2,4	6	0	3	0	0	0	0	0
1,2,3,4	7	0	2	14	2	6	0	0
No. of isolates tested		33	63	28	41	16	34	

CROWN RUST OF OATS

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From the ten samples of oat crown rust received, eight isolates were successfully cultured and were all identified as the common race 251. This is avirulent on commercial cultivars that carry the cv. Landhafer resistance.

Ten samples of oat crown rust were received in 1988. The eight isolates of Puccinia coronata successfully cultured were tested on the International set of cultivars which are Anthony, Victoria, Appler, Bond, Landhafer, Santa Fé, Ukraine, Trispernia, Bondvic and Saia.

Table 1. Locations and cultivars from which viable crown rust samples were received with virulences identified for each sample

Location	Cultivar	Race
ENGLAND (ADAS region)		
South-west	Wild oat	251
South	Aintree (2), Commander, Breeding lines (2)	251
East-central	Pennal	251
WALES		
Dyfed	Breeding line (winter oat)	251

All isolates were identified as being race 251. This virulence combination is compatible with the differential cultivars, Appler, Bond and Saia and occurs commonly in the UK.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1989

Variety diversification schemes to reduce the spread of disease in winter wheat and spring barley have been produced by the UKCPVS Committee since 1975. In 1986, the barley scheme was expanded to include both winter and spring varieties. This year, spring wheat varieties have been added to the wheat scheme. The two schemes which follow update those in the last Annual Report.

The schemes are used to encourage farmers to grow a number of varieties possessing different specific resistances, either in adjacent fields or in the same field as a variety mixture. Disease is unlikely to spread between varieties possessing different specific resistances because spores generated on one variety are largely non-virulent on the other.

The general principles and history of the UK diversification schemes have been described by Priestley and Bayles (1980). Evidence that the schemes are effective in reducing the spread of disease has been summarised by Priestley and Bayles (1982) and the use of cultivar mixtures as a method of disease control has been reviewed by Wolfe, Barrett & Jenkins (1981).

The schemes currently available are for yellow rust and mildew of wheat and for mildew of barley. The UKCPVS has also examined the possibility of including brown rust in the wheat scheme. With current varieties, diversification for brown rust is not effective, but the position will be reviewed regularly. Varieties with good resistance to brown rust are available and should be grown in areas where there is a high risk of the disease occurring. Further details of specific resistances to brown rust in wheat varieties are given in the paper on 'Brown Rust of Wheat' in this and previous UKCPVS Annual Reports.

REFERENCES

PRIESTLEY R H & BAYLES R A (1980). Varietal diversification as a means of reducing the spread of cereal diseases in the United Kingdom. Journal of the National Institute of Agricultural Botany, 15, 204-214

PRIESTLEY R H & BAYLES R A (1982). Evidence that varietal diversification can reduce the spread of cereal diseases. Journal of the National Institute of Agricultural Botany, 16, 31-38

WOLFE M S, BARRETT J A & JENKINS J E E (1981). The use of cultivar mixtures for disease control. In Strategies for the control of cereal diseases Ed J F Jenkyn & R T Plumb, 73-80. Blackwell Scientific Publications, Oxford.

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST AND MILDEW IN WHEAT 1989 (Revised March 1989)

Severe infections may result if yellow rust or mildew spread between varieties which are susceptible to the same races of the pathogens. This risk is reduced if varieties with high levels of resistance are grown. Disease spread can be limited further by sowing different varieties in neighbouring fields, provided that they are not susceptible to the same races of yellow rust or mildew. The Diversification Scheme should be used to choose varieties to grow adjacent to one another.

Choosing varieties to grow together

1) Decide upon first-choice variety and locate its Diversification Group (DG). (W) = winter variety; (S) = spring variety.
2) Find this DG under 'Chosen DG' down left hand side of table.
3) Read across table to find the risk of disease spread for each companion DG.
   + = low risk of spread of yellow rust or mildew
   Y = risk of spread of yellow rust M = risk of spread of mildew
   y = suspected risk of spread of yellow rust - further tests in progress

Varieties in yellow rust DG 1 and mildew DG A have good resistance to disease spreading from any variety and can therefore be used to diversify with varieties in all DGs, including others in DG 1/DG A.
Varieties in yellow rust DG 0 and mildew DG Z are susceptible to disease spreading from any variety and therefore do not contribute to diversi

DG 0A
Alexandria (S)
Sober (S)

DG 1A
Apostle (W)
Fenman (W)
Parade (W)
Pastiche (W)
Canon (S)

DG 1E
Aquila (W)

DG 1H
Boxer (W)
Mercia (W)
Mission (W)

DG 1K
Rendezvous(W)

DG 1Z
Jerico (S)
Tonic (S)
Wembley (S)

DG 2H
Riband (W)

DG 3A
Minaret (S)

DG 3B
Norman (W)

DG 3L
Axona (S)

DG 7G
Apollo (W)
Slejpner (W)

DG 8B
Galahad (W)

DG 9B
Avalon (W)
Brigand (W)

DG 12B
Brimstone (W)
Longbow (W)

DG 14A
Brock (W)

DG 14Z
Soleil (W)

DG 15G
Hornet (W)
Mandate (W)

DG 15Z
Fortress (W)

Chosen DG	Companion DG: 0A	1A	1E	1H	1K	1Z	2H	3A	3B	3L	7G	8B	9B	12B	14A	14Z	15G	15Z
0A	Y	+	+	+	+	+	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
1A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1E	+	+	M	M	+	M	M	+	+	+	+	+	+	+	+	M	+	M
1H	+	+	M	M	M	M	M	+	+	+	+	+	+	+	+	M	+	M
1K	+	+	+	M	M	M	M	+	M	+	+	M	M	M	+	M	+	M
1Z	+	+	M	M	M	M	M	+	M	M	M	M	M	M	+	M	M	M
2H	Y	+	M	M	M	M	YM	Y	Y	Y	Y	+	+	Y	+	M	Y	yM
3A	Y	+	+	+	+	+	Y	Y	Y	Y	y	+	Y	Y	Y	Y	Y	Y
3B	Y	+	+	+	M	M	Y	Y	YM	Y	y	M	YM	YM	Y	YM	Y	YM
3L	Y	+	+	+	+	M	Y	Y	Y	YM	y	+	Y	Y	Y	YM	Y	YM
7G	Y	+	+	+	+	M	Y	y	y	y	YM	+	+	y	+	M	yM	yM
8B	Y	+	+	+	M	M	+	+	M	+	+	YM	M	M	+	M	+	M
9B	Y	+	+	+	M	M	+	Y	YM	Y	+	M	YM	M	+	M	+	M
12B	Y	+	+	+	M	M	Y	Y	YM	Y	y	M	M	YM	+	M	y	yM
14A	Y	+	+	+	+	+	+	Y	Y	Y	+	+	+	+	Y	Y	+	+
14Z	Y	+	M	M	M	M	M	Y	YM	YM	M	M	M	M	Y	YM	+	M
15G	Y	+	+	+	+	M	y	Y	Y	Y	yM	+	+	y	+	+	YM	YM
15Z	Y	+	M	M	M	M	yM	Y	YM	YM	yM	M	M	yM	+	M	YM	YM

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN BARLEY 1989 (Revised March 1989)

Severe infections may result if mildew spreads between varieties which are susceptible to the same race of the pathogen. This risk is reduced if varieties with high levels of resistance are grown. Spread can be limited further by sowing different varieties in neighbouring fields provided that they are not susceptible to the same races of mildew. The Diversification Scheme should be used to choose varieties to grow adjacent to one another.

Choosing varieties to grow together

1) Decide upon first-choice variety and locate its Diversification Group (DG).
   (W) = winter variety; (S) = spring variety
2) Find this DG number under 'Chosen DG' down left hand side of table.
3) Read across table to find the risk of mildew spread for each companion DG.
   + = low risk of spread of mildew
   M = high risk of spread of mildew

Varieties in DG 1 have good resistance to mildew spreading from any variety and can therefore be used to diversify with varieties in all DGs, including others in DG 1.
Varieties in DG 0 are susceptible to mildew spreading from any variety and therefore do not contribute to diversification.

DG 0
Concert (W)
Finesse (W)
Frolic (W)
Gaulois (W)
Gerbel (W)
Halcyon (W)
Igri (W)
Magie (W)
M. Otter (W)
Melusine (W)
Mimosa (W)
Nevada (W)
Pastoral (W)
Panda (W)
Pirate (W)
Plaisant (W)
Posaune (W)
Target (W)
Vixen (W)
Corgi (S)
Golden Promise (S)

DG 1
Calix (W)
Masto (W)
Sonate (W)
Brenin (S)
Delphine (S)

DG 2
Atem (S)
Hart (S)

DG 3
Golf (S)

DG 4
Koala (W)
Pipkin (W)
Digger (S)
Sherpa (S)
Tyne (S)

DG 5
Cashmir (W)
Kaskade (W)
Puffin (W)
Waveney (W)
Blenheim (S)
Fergie (S)
Corniche (S)
Natasha (S)
Prisma (S)

DG 6
Marinka (W)
Montana (S)
Triumph (S)

DG 7
Regatta (S)

DG 8
Kym (S)

DG 9
Doublet (S)
Joline (S)
Klaxon (S)
Oboe (S)

DG 10
Carrera (W)
Kira (W)
Torrent (W)

DG 11
Camargue (S)

Chosen DG	Companion DG 0	1	2	3	4	5	6	7	8	9	10	11
0	M	+	M	M	M	M	M	M	M	M	M	M
1	+	+	+	+	+	+	+	+	+	+	+	+
2	M	+	M	+	+	+	+	+	+	+	+	+
3	M	+	+	M	+	M	+	M	M	M	+	+
4	M	+	+	+	M	+	+	+	+	+	+	M
5	M	+	+	M	+	M	M	+	+	M	+	M
6	M	+	+	+	+	M	M	+	+	M	+	M
7	M	+	+	M	+	+	+	M	M	M	+	+
8	M	+	+	M	+	+	+	M	M	M	+	+
9	M	+	+	M	+	M	M	M	M	M	+	+
10	M	+	+	+	+	+	+	+	+	+	M	+
11	M	+	+	+	M	M	M	+	+	+	+	M