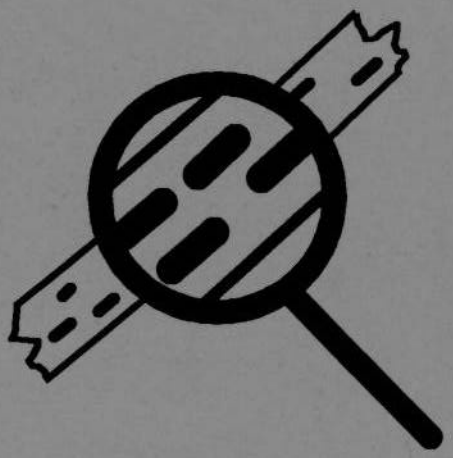
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1990 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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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 two testing centres:

- National Institute of Agricultural Botany, Cambridge, for mildew and yellow rust 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 such as mobile nurseries are also used.

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 official trials. 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 and 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 numbered 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 1990

Mildew of wheat

Virulences corresponding to the mildew resistance genes most widely used in wheat cultivars in Britain, WMR 2, 4b, 6, 7 and 8, were recorded at high frequencies for at least the third consecutive year. Many isolates of wheat carried virulences enabling them to infect a wide range of cultivars. This indicates that these specific resistances are no longer effective in controlling mildew. However, most currently recommended cultivars have moderately effective background resistance.

Yellow rust of wheat

The frequency of WYV 9 remained above 90% for a second year and the combination WYV 6,9 (virulence for Hornet, Haven and Beaver) increased to a frequency of 60%. Isolates continue to become more complex, enabling single pathotypes to infect an ever wider range of cultivars.

Brown rust of wheat

Seedling tests showed that the new winter wheat cultivars Haven and Admiral carry WBR 1, virulence for which is common. Adult plant field tests showed that Tara carries this resistance and additional adult plant resistance effective against WBR 1 virulent isolates. The adult plant resistance of Apostle, Hereward, Urban, Pastiche and Yuri was effective against both field isolates tested.

Mildew of barley

BMR 9 (resistance gene mlo) remained effective during 1990. BMR 3, 4, 7, 8 and 10 may provide moderate resistance, but the frequency of the corresponding virulence factors will increase rapidly if varieties with these resistance factors are grown more widely. The most frequent virulence phenotypes were complex, with about 70% of isolates carrying 5 or more virulence factors.

In N Ireland no virulence for the Atem group (BMR 9) was detected. Races virulent on the Digger group (BMR 10) also remained at a low frequency. This is despite the fact that both groups of cultivars are relatively popular in N Ireland.

Yellow rust of barley

Yellow rust of barley was again very rare in 1990 with only one sample being received from Northumberland.

Brown rust of barley

Brown rust was the most severe disease of barley in 1990. Seedling test results indicated that virulence for Triumph continued to decline. Winter barley cultivars grown in field isolation nurseries displayed a range of quantitative responses to Triumph-virulent pathotypes with Puffin showing good levels of resistance. The resistance of the spring barleys Corniche, Redstart and Chad was effective in the field nurseries.

Rhynchosporium of barley

Three new races, all carrying virulence to the differential La Mesita (BRR 5), were identified from isolates cultured from infected leaf samples of Pipkin which also carried BRR 5. The frequency of virulence for Osiris (BRR 6) was at an increased level in 1990, this virulence having previously been identified in only one naturally infected field sample. Seedling tests suggest that there is some erosion of the resistance carried by Digger, although this cultivar remains highly resistant in adult plant field tests.

Net blotch of barley

Two of the isolates tested were widely virulent, with one carrying virulences compatible with 12 of the 13 seedling differential cultivars. Heritage, Decor and Tyne were the most susceptible spring barley cultivars tested in an artificially inoculated field nursery, but disease levels were very low.

Mildew of oats

Virulence for the resistance derived from Avena barbata was at an increased frequency in 1990 (0.34). All isolates carrying this virulence were samples from oat breeding nurseries at the Welsh Plant Breeding Station, where breeding lines incorporating this resistance are grown. Race 5 (OMV 1,2,3) was again predominant.

Crown rust of oats

Glasshouse seedling tests identified 4 races of Puccinia coronata all of which had been previously identified in the UK, although only one, race 251, occurs commonly.

Barley Yellow Mosaic Virus

Two isolates of barley yellow mosaic virus (BaYMV) virulent on cultivars resistant to the common virus isolates were received. Amongst other samples, BaYMV was again more frequent than barley mild mosaic virus except on malting cultivars.

Sources of resistance of wheat and barley to powdery mildew

In a field trial of sources of resistance to powdery mildew, the genes Pm3b, carried by Chul, and Pm17, in Amigo, provided resistance to wheat mildew. Several barley lines, developed for genetic analysis, were resistant to mildew; one of the genes in these stocks, Mla3, is present in German and Swedish varieties. BMR9 (mlo) continues to control barley mildew effectively.

LEAF DISEASE STATUS IN UK CEREAL CROPS 1990

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ADAS cereal disease surveys provide a record of annual variations in disease incidence in England and Wales. Leaf infections in 1990 were below the levels recorded in recent years although incidence of brown rust on wheat and winter barley was higher than in 1989.

INTRODUCTION

ADAS Cereal Disease Surveys provide an annual snapshot of disease incidence severity on crops selected at random in England and Wales. Samples are collected at milky ripe, GS71-73 irrespective of fungicide treatment. In 1990 over 90% of samples were from crops which received one or more fungicide sprays.

WINTER WHEAT

National levels of infection on leaf 2 are shown in Table 1 in relation to the ADAS regions from which samples were collected. A key to the region abbreviation is given in the Annex. Septoria tritici and mildew were no more important than brown rust, occurring at the similar low levels to those found in 1989. Yellow rust was less severe than last year occurring at a similar level to that found in 1988. The low level of the septoria diseases was probably a reflection of the long periods of dry weather which occurred in the spring.

Table 1 Regional foliar disease levels. Second leaf (average percentage leaf area affected)

Region	No of Samples	Yellow rust	Septoria tritici	Mildew	Brown rust	Septoria nodorum
NO(O)	22	0.12	0.17	0.63	0.02	0.02
NO(L)	33	0.28	0.69	0.77	0.11	0.00
M & W	64	0.12	0.51	0.94	0.41	0.02
EAST	160	0.32	0.22	0.35	0.43	0.01
SE(W)	28	0.14	1.44	0.31	0.94	0.01
SE(R)	36	0.10	0.48	0.55	1.68	0.04
SW(B)	27	0.37	1.13	0.42	0.92	0.08
SW(S)	6	0.00	5.77	0.23	0.03	0.02
WALES	29	0.64	0.18	0.37	0.17	0.01
National (stratified)	354	0.24	0.61	0.52	0.59	0.02

Effect of Cultivar

Mercia was the most popular cultivar for the second consecutive year, accounting for a quarter of the crops in the stratified sample compared to 30% in 1989. Avalon continued to decline in popularity, as did Slejpner and Galahad. Riband, Apollo and Hornet increased in popularity.

Table 2 Distribution of cultivars between regions (number of samples)

Region	Variety							
	Mercia	Galahad	Riband	Apollo	Hornet	Avalon	Slejpner	Other
NO(O)	8	2	5	2	0	0	3	2
NO(L)	7	3	7	3	3	2	3	5
M & W	16	10	10	6	4	6	3	9
EAST	33	12	22	24	28	7	9	25
SE(W)	9	4	1	4	4	1	2	3
SE(R)	11	2	0	5	2	3	2	11
SW(B)	11	6	2	1	0	2	0	5
SW(S)	0	3	0	0	0	1	0	2
WALES	6	10	1	2	3	2	2	3
National% (stratified)	25.7	11.0	13.6	12.1	11.3	5.9	5.1	15.3

Other:- Pastiche, Rendezvous, Brock, Fortress, Carolus, Camp Remy, Norman, Sperber, Haven, Beaver, Hobbit, Futur, Urban.

The effects of cultivar on disease levels can be modified by regional distribution and the spray regimes used. However, the relatively high levels of yellow rust on Slejpner (for the third successive year) and on Hornet (for the second year) and the low level recorded on Mercia are consistent with the NIAB resistance ratings. Brown rust was more severe on Avalon than on other cultivars but was seldom seen at recordable levels on Slejpner (Table 3). In general, however, foliar disease severity was too low to enable comparisons to be made between cultivars.

Table 3 Varietal foliar disease levels. Second leaf (average percentage leaf area affected)

Cultivar	No of Samples	Mildew	Septoria tritici	Yellow rust	Brown rust	Septoria nodorum
Mercia	91	0.52	0.34	0.02	0.81	0.01
Galahad	39	0.26	2.09	0.08	0.63	0.01
Riband	48	0.19	0.72	0.03	0.47	0.01
Apollo	43	0.92	0.06	0.03	0.67	0.04
Hornet	40	0.90	0.58	1.18	0.05	0.00
Avalon	21	0.78	0.74	0.02	2.13	0.08
Slejpner	18	0.24	0.18	0.74	0.00	0.00

Winter Barley

National infection levels on leaf 2 are shown in Table 4.

The highest levels of brown rust were found in the East and South-East (Wye) areas, with more than 10% of leaf 2 affected in South-East (Wye) for the second consecutive year. High levels were also recorded in the South-West and Wales (Table 4). However, apart from the Eastern region and the Midlands, the disease was slightly less severe than in 1989.

Mildew was less severe than in 1989 in all regions except the North (Newcastle) and the South-West. In the North (Leeds), the Midlands and West, East and South-East, levels of the disease were lower than in any previous survey year.

The highest levels of rhynchosporium were seen in the South-West and Wales, and of net blotch in the South-East (Reading) and South-West (Bristol) areas. However, in most regions, both diseases were recorded at their lowest level since surveys began in 1981.

Table 4. Regional foliar disease levels. Second leaf (average percentage leaf area affected)

Region	No of Samples	Mildew	Brown Rust	Net Blotch	Rhyncho sporium	Septoria	Seleno phoma
NO(N)	35	2.73	2.78	0.04	0.02	0.00	0.00
NO(L)	39	1.72	3.91	0.02	0.06	0.01	0.00
M & W	82	3.04	5.65	0.06	0.12	0.00	0.00
EAST	80	0.77	7.23	0.16	0.14	0.01	0.00
SE(W)	30	0.85	10.10	0.12	0.06	0.00	0.00
SE(R)	35	0.56	4.50	0.25	0.04	0.00	0.00
SW(B)	34	1.69	6.93	0.26	0.30	0.00	0.00
SW(S)	24	1.93	6.53	0.03	2.82	0.00	0.00
WALES	28	2.31	7.11	0.02	0.66	0.01	0.01
National (stratified)	328	1.65	5.68	0.11	0.32	0.00	0.00

Effect of cultivar

For the first time since 1981, Igri was not the most widely grown cultivar (Table 5) its share of the crops in the stratified sample being only half that in 1989. There was also a decline in the number of crops of Magie. By contrast, the number of crops of Marinka doubled to 30% of the total making it by far the most popular cultivar.

Table 5 Distribution of cultivars between regions (number of samples)

Region	Variety							
	Marinka	Igri	Magie	Torrent	Pipkin	Plaisant	Halcyon	Other
NO(N)	8	6	4	3	0	1	1	12
NO(L)	11	4	4	3	0	3	3	11
M & W	28	12	10	6	2	5	1	18
EAST	13	5	11	4	13	4	10	20
SE(W)	10	2	7	3	2	1	2	3
SE(R)	12	2	2	2	3	4	3	7
SW(B)	17	2	1	2	4	3	1	4
SW(S)	10	9	2	1	0	0	0	2
WALES	15	3	2	3	0	0	0	5
National % (stratified)	30.2	11.3	10.7	6.7	6.7	6.4	5.8	22.3

Other:- Frolic, Kira, Panda, Maris Otter, Finesse, Melusine, Pastoral, Gaulois, Sonja, Kashmere, Concert, Nevada, Express, Tipper, Monica.

It is difficult to draw conclusions from varietal disease levels because of the possibility of confounding effects from regional distribution and fungicide usage on disease. Magie and Torrent carried the highest levels of brown rust (Table 6), and, as in 1989, there was more mildew on Magie and Marinka than on other popular varieties. Igri had the highest level of rhynchosporium for the third successive year, and net blotch was more severe on Igri and Plaisant than on other cultivars. In general the disease levels found reflected the NIAB disease resistance ratings.

Table 6. Varietal foliar disease levels. Second leaf (average percentage leaf area affected)

Variety	No of Samples	Mildew	Brown Rust	Net Blotch	Rhyncho sporium	Septoria	Seleno phoma
Marinka	99	1.84	4.85	0.00	0.04	0.00	0.00
Igri	37	1.11	2.94	0.31	1.88	0.00	0.00
Magie	35	3.63	10.02	0.10	0.10	0.00	0.00
Torrent	22	1.60	15.26	0.09	0.07	0.00	0.00
Pipkin	22	0.84	2.47	0.00	0.23	0.00	0.00
Plaisant	21	1.64	5.96	0.37	0.11	0.01	0.00
Halcyon	19	0.60	1.95	0.06	0.11	0.00	0.00
Frolic	13	1.41	4.15	0.01	0.02	0.00	0.01
Kira	14	0.66	2.29	0.04	0.09	0.01	0.00

ANNEX

ADAS Regions used in the survey
NO(N) Cumbria, Northumberland, Durham
NO(L) Yorkshire, Humberside
M & W Midlands & West
SE(W) South East - Kent, Surrey, East Sussex
SE(R) South East - Remainder of SE region
SW(B) South West - Bristol area
SW(S) South West - Cornwall & Devon

MILDEW OF WHEAT

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Virulences corresponding to the mildew resistance genes most widely used in wheat cultivars in Britain were recorded at high frequencies for at least the third consecutive year. Many isolates of wheat mildew carried virulences enabling them to infect a wide range of cultivars.

INTRODUCTION

High levels of virulences corresponding to the resistance genes used most widely in wheat cultivars in Britain (WMR 2, 4b, 6, 7 and 8; genes *Pm2*, *Pm4b*, *Pm6*, *Pm8*, *Mli*) have been recorded in the wheat powdery mildew surveys in 1988 and 1989 (Slater *et al.* 1989, Brown *et al.* 1990). Consequently these resistance genes no longer provide resistance to powdery mildew in Britain. The survey in 1990 monitored the frequencies of virulences matching the main resistance genes, and also the frequencies of virulences matching other unidentified resistances.

Work for the wheat powdery mildew survey moved to NIAB, Cambridge in 1990, and virulence testing began in July.

METHODS

Isolates were derived from samples of infected leaves taken in July from variety trials plots of winter and spring wheat at: NIAB, Cambridge (174 isolates), Headley Hall, West Yorkshire (14 isolates), Dunmow, Essex (66 isolates), Lincolnshire (15 isolates), and from crops in Cornwall (6 isolates), Devon (5 isolates) and Rutland (5 isolates).

The source cultivars were:

Alexandria, Apostle, Hereward, Pastiche	WMR0	35 isolates
Avalon, Galahad, Axial, Talon, Yuri	WMR2	31 isolates
Torfrida	WMR2,4?	10 isolates
Hornet, Tara, Dean	WMR2,7	23 isolates
Brock	WMR2,'Talent'	4 isolates
Beaver, Haven	WMR7	28 isolates
Slejpner	WMR7,x	5 isolates
Apollo	WMR7,y	5 isolates
Mercia, Urban	WMR8	26 isolates
Tonic	WMR5,8,p	5 isolates
Axona	WMR'Axona'	5 isolates
Riband	WMR2,4,8	10 isolates
Parade	WMR2,6,8	6 isolates
19 cultivars of unknown resistance		95 isolates

Single colony isolates were taken from seedlings of Cerco exposed on a high roof at NIAB, Cambridge in July and October (roof isolates). A total of 86 isolates was tested from the July sample, and 76 from October.

All isolates were tested for virulence on detached leaves of the differential cultivars listed in Table 1. Virulence was determined according to the infection types of Moseman *et al.* 1965.

Table 1. *Differential cultivars used for determining virulence factors in isolates of wheat powdery mildew in 1990.*

WMR Group	Resistance genes	Cultivar
0		Cerco
2	*Pm2*	Galahad
4b	*Pm4b*	Armada
2,6	*Pm2, Pm6*	Brimstone
2,7	*Pm2, Pm8*	Hornet
7,x	*Pm8*, ?	Slejpner
7,y	*Pm8*, ?	Apollo
8	*Mli*	Mercia
5,8,p	*Pm5, Mli*, ?	Tonic [1]
5,8,q	*Pm5, Mli*, ?	Broom
2,'Talent'	*Pm2*, ?	Brock
'Sona'		Wembley
'Axona'		Axona [2]
7	*Pm8*	Beaver
7	*Pm8*	Haven

[1] Not all isolates were tested against Tonic.
[2] Only a few isolates were tested against Axona.

RESULTS

Virulence Frequencies

The frequencies of WMV 2, 4, 6, 7, 8, x, y and 'Axona' in the leaf and roof samples are given in Table 2. Shown for comparison are data from the 1989 survey for WMV 2, 4, 6, 7 and 8.

All virulences were recorded at high frequencies, with the exception of WMV'Axona'. Since not all isolates were tested on Axona, the frequency of this virulence may have been underestimated. Axona is not widely grown and selection for WMV'Axona' is unlikely to be strong.

Differences in the frequencies of WMV 2, 4, 6, 7 and 8 from 1989 mostly follow changes in the acreage of cultivars with the corresponding resistances. Thus the frequency of WMV2 remains very high with Avalon, Galahad (both WMR2), Hornet (WMR2,7) and Riband (WMR2,4,8) making up about 40% of the certified seed acreage in 1990; WMV4 has increased slightly following an increase in the acreage of Riband; and WMV7 has changed

little with Hornet (WMR2,7), Apollo (WMR7,y) and Slejpner (WMR7,x) making up about 30% of the seed acreage. The large decrease in the frequency of WMV8 is surprising, since Mercia (WMR8) and Riband made up about 30% of the seed acreage in 1990.

Most of the virulence factors occurred at high frequencies on host cultivars where they were unnecessary for infection. Data are not presented for the frequencies of unnecessary virulences (ie. where virulences from each isolate matching the resistances of its source cultivar have been excluded) since they are very similar to the complete set of data. This suggests that the virulences were at too high a frequency to be greatly influenced by host selection.

Table 2. *Frequency of wheat powdery mildew virulence factors in isolates from infected leaves (leaf sample), and in random samples of single colony isolates formed by airborne spores (roof samples).*

Virulence factors	Frequency of virulence factors (%) Leaf sample July 1990	Roof sample July 1990	Roof sample Oct. 1990	Leaf sample 1989 [1]
2	99	99	91	94
4	52	60	56	44
6	69	67	75	89
7	66	74	81	87
8	34	29	25	61
7,x	65	77	73	
7,y	41	41	54	
'Axona'	5	- [2]	- [2]	
Number of isolates tested	290	86	79	70

[1] Brown *et al.* 1990.
[2] Roof isolates were not tested against Tonic (WMR5,8,p) or Axona.

Uncharacterized Resistances

The additional resistances carried by the WMR7 cultivars Slejpner (WMR7,x) and Apollo (WMR7,y) were recorded at high frequencies and will not be effective. All isolates virulent on Hornet (WMR2,7) were also virulent on Slejpner, although in previous years this has not been the case (Slater *et al.* 1989). The large acreages of Slejpner prior to 1989 probably selected very strongly for WMV7,x, and consequently most isolates with WMV7 now also have WMVx.

There has been some suggestion that Beaver and Haven have additional resistance factors. However, both cultivars were susceptible to all isolates with WMV2,7, and it seems likely that these resistance factors are non-specific, giving additional resistance in the field.

Several isolates were found which were virulent on Tonic (WMR5,8,p), but avirulent on Mercia (WMR8). Mercia therefore appears to have an additional resistance factor. This may explain the low frequency of WMV8 (Table 2), since if Mercia has WMR8+r, isolates with WMV8 but not WMVr would be avirulent on Mercia, leading to an underestimate of the frequency of WMV8. It is intended to use both Mercia and Aquila (WMR8) as differential cultivars in the 1991 survey.

Complexity of Isolates

The great majority of isolates were complex, and carried 4 or more virulence factors. Many isolates would be able infect several commonly grown cultivars. The frequencies of some major phenotypes are given in Table 3.

Table 3. *Frequencies of some major wheat mildew virulence phenotypes, defined by WMV 2, 4, 6, 7 and 8.*

WMV phenotype	Frequency of virulence phenotype (%) Leaf sample July 1990	Roof sample July 1990	Roof sample Oct. 1990
2,4,8	5	3	1
2,4,6,7	28	38	48
2,4,6,8	3	5	5
2,4,6,7,8	6	1	6
2,6,7	14	16	20
2,6,7,8	6	0	6
Other phenotypes	14	10	8
No. of isolates tested	290	86	79

Resistance Factors in Currently Recommended Cultivars

The resistance factors in winter and spring wheat cultivars currently recommended by NIAB and the Scottish Agricultural Colleges (SAC) are given in Table 4.

Table 4. *Mildew resistance factors of wheat cultivars currently recommended by NIAB and SAC.*

WMR 0		**WMR 2,4,8**		**WMR 'Axona'**	
Hereward	(W)	Riband	(W)	Axona	(S)
Pastiche	(W)				
Alexandria	(S)	**WMR 2,'Talent'**		**Unknown**	
		Brock	(W)	Canon	(S)
WMR 2					
Avalon	(W)	**WMR 2,7**			
Galahad	(W)	Hornet	(W)		
Norman	(W)				
Talon	(W)	**WMR 5,8,p**			
		Tonic	(S)		
WMR 7					
Apollo (+y)	(W)	**WMR 8**			
Beaver	(W)	Mercia (+r)	(W)		
Haven	(W)				
Slejpner (+x)	(W)				

(W) winter wheat, (S) spring wheat

CONCLUSIONS

The high frequencies of isolates of wheat powdery mildew carrying virulences corresponding to the specific resistances most widely used in wheat cultivars in Britain indicate that the resistances are no longer effective in controlling mildew. However, most currently recommended cultivars have moderately effective background resistance. A diversification scheme to reduce the spread of mildew between crops continues to be of little value.

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YELLOW RUST OF WHEAT

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The frequency of WYV 9 remained above 90% for a second year and that of the combination WYV 6,9 rose from 47% in 1989 to 60%. The most commonly identified pathotype was WYV 1,2,3,4,6,9. This complex virulence combination is now frequently associated with the adult plant virulences WYV 13 and WYV 14.

INTRODUCTION

The principal aim of the wheat yellow rust survey is to detect increased virulence for specific resistances to Puccinia striiformis (WYR factors). In addition, specific resistances in current and new cultivars are identified. 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	Gene	Type*	Differential Cultivar(s)**	WYV detected
WYR 1	Yr 1	O	Chinese 166, Maris Templar	1957
WYR 2	Yr 2	O	Heine V11, Brigand	1955
WYR 3	Yr 3a + 4a	O	Vilmorin 23, Cappelle Desprez	1932
WYR 4	Yr 3b + 4b	O	Hybrid 46, Avalon	1965
WYR 5	Yr 5	O	T. spelta album	
WYR 6	Yr 6	O	Heines Kolben, Maris Ranger	1958
WYR 7	Yr 7	O	Lee, Tommy	1971
WYR 8	Yr 8	O	Compair	1976
WYR 9	Yr 9	O	Riebesel 47/51, Clement	1974
WYR 10	Yr 10	O	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 1990

WYR 6,9	Hornet	
WYR 9	Kavkaz/4X Federation	
WYR R (?7,9)	Tara	
WYR Rx	Talon	) not included in
WYR Rx	Torfrida	) all tests

* O = Overall A = Adult Plant

** Differential cultivars used in 1990 seedling tests are underlined

METHODS

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

1990 isolates

Although the 1990 yellow rust epidemic was less widespread than that of 1989, infection levels were very high in some trials and crops.

88 samples were received. From these, 67 isolates were made and tested for virulence in seedling tests, using the differential cultivars indicated in Table 1.

1989 isolates

19 isolates (Table 2) were tested on adult plants of 33 cultivars in Polythene tunnels and on seedlings of the same cultivars in controlled environment chambers. The isolates comprised two control isolates brought forward from 1988, 14 new isolates from the 1989 survey and one isolate from a 1989 inoculated test. All except two of the 1989 isolates possessed the virulence combination WYV 6,9. One of these (89/205) was selected for its apparent combination of virulence for WYR 7 and WYR 9, although in subsequent seedling tests the cultivar Tara (WYR R - ?7,9) proved to be resistant. The other isolate (89/88) was chosen because it originated from the resistant cultivar Pastiche.

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

Isolate Code	Source		WYV Factors
	Cultivar	Location	
88/127	NL candidate	Cambs	1,2,3,4,7,14
88/128	Fortress	Scotland	1,2,3,4,6,9,14
89/60	Apollo	Wales	1,2,3,4,6,9
89/76	Apollo	Suffolk	1,2,3,4,6,9
89/78	Hornet	Northumberland	1,2,3,4,6,9
89/88	Pastiche	Norfolk	2,3,4,9
89/113	Hornet	Scotland	1,2,3,4,6,9
89/134	Hornet	Avon	1,2,3,4,6,9
89/148	Hornet	Essex	1,2,3,4,6,9
89/156	Haven	Cambs	2,3,4,6,9
89/162	Hornet	Scotland	1,2,3,4,6,9
89/194	Haven	Northumberland	1,2,3,4,6,9
89/199	Haven	Scotland	1,2,3,4,6,9
89/203	CWW 88/2	Kent	1,2,3,4,6,9
89/205	Brock	Norfolk	1,2,3,4,7,9
89/208	Haven	Essex	1,2,3,4,6,9
89/213	Beaver	Northumberland	1,2,3,4,6,9
89/219	Apostle	Wiltshire	1,2,3,4,6,9
89/A2	Haven	PT, inoc 88/149	1,2,3,4,6,9,14

RESULTS

1990 Survey isolates

Virulence frequencies are given in Table 3.

Table 3. Virulence factor frequency (%)

WYV Factor	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
WYV 1	73	73	83	95	71	63	85	75	76	78	87	68	62	85
WYV 2	100	97	100	100	100	100	100	100	100	100	100	100	100	100
WYV 3	100	100	100	85	95	100	100	100	100	100	100	100	100	100
WYV 4	24	27	17	15	29	37	20	31	45	70	47	78	97	91
WYV 5	0	0	0	0	0	0	0	0	*	*	*	*	*	*
WYV 6	16	26	17	25	31	29	26	64	90	96	89	72	57	69
WYV 7	8	0	0	0	5	5	0	3	3	22	8	6	2	9
WYV 8	4	0	0	0	0	2	0	0	*	*	*	*	*	*
WYV 9	0	0	0	0	5	2	23	31	3	4	5	66	99	94
WYV 10	0	0	0	0	0	0	0	0	*	*	*	*	*	*
Virulence for Hornet WYR 6,9								*	*	0	0	42	47	60
" " Tara WYR R (?7,9)								*	*	*	*	*	*	18
No. of isolates	26	66	30	20	42	41	63	36	29	23	52	71	156	67

* differential not included in test

The frequency of WYV 9 remained above 90%, while the frequency of WYV 6 increased, due presumably to the influence of cultivars with the combined resistance WYR 6,9 (predominantly Hornet and Haven). 61% of isolates tested were of the WYV 1,2,3,4,6,9 pathotype.

The source of isolates is shown in Tables 4a and 4b. Isolates came largely from the eastern counties and Scotland. From Yorkshire northwards, all isolates possessing virulence for WYR 9 also possessed virulence for WYR 6. Further south, a number of isolates possessed virulence for WYR 9 without virulence for WYR 6, although the proportion of these was lower than in 1989. There was no apparent regional bias in cultivars sampled to account for this observation. The main cultivars sampled were Hornet, Haven, Slejpner, Apollo and Riband. The WYV 6,9 combination was detected in more than half the isolates derived from cultivars without the corresponding WYR 6,9 resistance.

12 isolates were virulent on Tara (WYR R -?7,9), giving reaction types varying from an intermediate 2.5 - 3.0 to 4.0. All isolates giving type 4 reactions on Tara were also virulent on the WYR 7 and WYR 9 differentials.

Table 4a. Source of 1990 Isolates, classified by Region

Region	Virulence Characters: WYV 9 and WYV 6	Virulence Characters: WYV 9 without WYV 6	Virulence Characters: Other	Total
East Anglia	12	8	1	21
East Midlands	6	7	1	14
South East	8	3	2	13
South West	2	0	0	2
Yorks/Humberside	1	0	0	1
North East	6	0	0	6
Scotland	10	0	0	10

Table 4b. Source of 1990 Isolates, classified by Cultivar

Cultivar		Virulence Characters: WYV 9 and WYV 6	Virulence Characters: WYV 9 without WYV 6	Virulence Characters: Other	Total
Hornet	(WYR 6,9)	8	3	0	11
Haven	(WYR 6,9)	9	0	0	9
Slejpner	(WYR 9)	4	4	0	8
Apollo	(WYR 9)	4	2	0	6
Riband	(WYR 13)	3	2	1	6
Other		17	7	3	27

Adult plant tests

The results of adult plant tests in polythene tunnels are given in Table 5. The virulence factors attributed to each isolate are derived from seedling tests (virulence for overall resistances) and 1990 adult plant tests (virulence for adult plant resistances).

With the exception of the three isolates at the extreme right of the table, isolates were broadly similar in pathogenicity, possessing the virulence combination WYV 1,2,3,4,6,9. The majority were also virulent on the adult plant resistances WYR 13 and WYR 14, demonstrating that the complex combination WYV 1,2,3,4,6,9,13,14 is now common.

Isolate 89/205 gave high levels of infection on WYR 7 and WYR 9 cultivars, but was not virulent on Tara, which may possess WYR 7,9 in combination with the adult plant resistance WYR 14 (W. Hollins, per comm). However, the results of subsequent tests of this isolate indicated that it comprised a mixture of two types, one virulent on WYR 7 and one virulent on WYR 9.

Isolate 88/127, with combined virulence for WYR 7 and WYR 14, gave high infection on Brock, confirming results obtained in 1989.

Twelve cultivars shown at the top of the table, including the five in tunnel tests for the first time (Talon, Tara, Hereward, Torfrida and Axial), maintained a high degree of adult plant resistance to all isolates.

Amongst the WYR 9 cultivars, the susceptibility of Hornet, Haven and Beaver to isolates possessing WYV 6,9 was confirmed. The relative levels of infection on Hornet and Haven varied from isolate to isolate, with Hornet generally being the more susceptible. There was no evidence that isolates derived from Haven itself were more highly adapted to the cultivar.

Apollo and Dean continued to exhibit a greater degree of resistance than the other WYR 9 cultivars. However, infection levels on the two cultivars varied widely from one WYV 9 isolate to another, indicating variation in virulence for adult plant components of resistance. The identity of any adult plant resistance is unclear, but there appeared to be some association between infection levels on Apollo and on M.Huntsman/Hustler (WYR 13).

Isolate 89/88 (WYV 2,3,4,9,14) gave high levels of infection on Slejpner, despite its lack of WYV 13. This lends further weight to doubts that Slejpner possesses WYR 13 (Annual Report for 1989).

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Table 5 Results of Adult Plant Tests 1990. Values are per cent leaf area infection (mean of 4 assessments)

Isolate		89/A2	89/60	89/76	89/208	89/78	89/134	89/156	88/128	89/213	89/219	89/203	89/148	89/162	89/113	89/194	89/199	89/205	88/127	89/88
Cultivar	WYV Factors / WYR Factors	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,(14)	1,2,3,4,6,7*,9,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,14	1,2,3,4,6,9,13,14	1*,2,3,4,6,7*,9,14	1,2,3,4,6,7*,9,13+,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,14	1,2,3,4,6,9,13,14	1,2,3,4,6*,7,9,13,14	1,2,3,4,7,(14)	2,3,4,9,14
Parade	R	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0
Boxer	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Arminda	0 + APR	0	0	0	0	0	0	0	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	1	0	0	0	0	0
Pastiche	0 + APR	1	0	0	0	0	2	1	0	0	0	0	2	2	0	0	1	1	0	1
Apostle	2,6 + APR	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Mercia	?3 + APR	0	0	1	1	0	1	1	0	1	0	0	2	2	2	2	1	1	0	0
Talon	Rx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
Tara	R(? 7,9)	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
Hereward	Rx	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Torfrida	Rx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Axial	1	1	0	1	0	1	1	0	0	2	1	0	3	3	0	1	2	2	0	0
M.Templar	1	4	2	4	9	3	8	5	9	10	7	11	11	11	14	11	10	7	3	0
M.Beacon	4	10	20	11	15	18	17	16	13	18	19	25	16	19	20	17	29	14	13	16
Avalon	4,14	0	2	5	4	2	2	5	5	4	5	5	7	5	6	6	5	7	1	5
Galahad	1,2,14	2	4	9	9	1	8	3	9	7	10	6	11	6	12	11	10	9	4	0
Kinsman	6,13	4	11	10	4	7	5	7	9	10	17	10	8	12	16	13	20	10	1	1
Norman	2,6	7	7	5	6	11	4	15	13	11	12	17	11	12	14	13	17	8	0	0
Longbow	1,2,16,13	4	11	13	6	4	4	2	5	8	12	5	11	9	15	12	13	10	1	1
M.Huntsman	2,13	9	6	3	9	2	12	5	8	16	13	10	11	9	11	13	15	5	4	2
Hustler	1,2,13	9	15	7	9	6	10	4	10	13	12	16	14	13	17	10	9	12	3	3
Riband	13	2	2	3	7	8	6	7	4	7	6	4	7	11	12	9	10	9	1	3
Hobbit	14	12	7	15	10	13	12	14	12	14	11	12	15	14	12	14	19	15	8	15
Clement	9	18	27	16	10	27	21	16	13	29	28	25	21	22	31	19	36	17	7	31
Slejpner	9	14	17	9	14	13	10	15	11	22	21	21	6	18	31	19	21	14	6	21
Apollo	9	6	5	4	6	3	10	1	7	9	9	7	10	8	11	14	9	2	2	1
Dean	9	4	2	1	3	3	8	2	2	5	3	4	9	3	5	8	6	2	0	5
Hornet	6,9	16	29	16	10	18	13	16	18	22	24	21	14	16	24	19	31	14	9	2
Haven	6,9	14	13	11	12	17	13	13	17	15	15	14	13	11	18	17	20	8	9	9
Beaver	6,9	17	7	8	9	13	9	7	12	12	12	18	11	12	16	14	14	6	8	0
Brock	7,14	6	0	13	0	1	0	8	11	4	0	0	2	1	0	1	0	12	11	1
Tommy	7	6	0	11	0	3	1	9	8	1	0	4	2	1	0	0	0	15	9	1
Urban	1	2	2	7	7	9	6	7	9	2	6	9	10	10	12	10	17	10	3	0

* = virulence not detected in seedling tests, indicating contamination
Rx = susceptible to some isolates at seedling stage, but resistance not identified
R = resistant to all isolates at seedling and A.P. stages
+ = not designated V13 in 1989 tests

BROWN RUST OF WHEAT

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Glasshouse seedling tests with isolates of *P.recondita* cultured from samples received in 1990 identified the winter wheat cvs Haven and Admiral as carrying WBR-1. Adult plant tests in field isolation nurseries identified cv. Tara as possessing additional adult plant resistance effective against isolates carrying WBV-1. Cvs Beaver and Dean were susceptible to an isolate carrying WBV-1 in 1990 conflicting with 1989 field test results when these two cultivars were identified as having WBR-1 plus additional resistance expressed at the adult plant stage of growth. The winter wheat cvs Apostle, Hereward, Urban and Pastiche were grouped together on the basis of 1989 glasshouse seedling and 1990 field results. The spring wheat cv. Yuri was also placed in this group.

GLASSHOUSE SEEDLING TESTS WITH 1990 ISOLATES

Wheat brown rust was more prevalent and was significantly more severe than in 1989 (Polley pers. comm.) and this was reflected in the high number (86) of samples received in 1990. This included 69 sent from the ADAS Cereal Disease Survey. Two samples were from Triticale (cv. Lasko), the rest being from a range of winter wheat cultivars. The 84 samples received from England were from 5 different ADAS regions (Table 1).

Table 1. Geographic location (ADAS region) of 1990 wheat brown rust samples

ADAS region	Number of samples
East	47
South-West	12
West-Central	11
South	6
East-Central	3

Five were of unknown geographic origin, and two were from Wales. Isolates were obtained from 58 of the samples of which 51 have been tested on differential cultivars which comprised the standard WBR reference cultivars, cv. Thatcher backcross lines, carrying different Lr resistance factors, and 6 other spring and winter wheat cultivars from the NIAB Recommended List and Recommended List trials (Table 2).

Table 2. Differential cultivars

Standard differential cultivars		Thatcher Lr lines	Spring* and winter cultivars
Clement	(WBR-1)	Lr 1	Yuri*
Maris Fundin	(WBR-2)	Lr 2a	Hussar
Norman	(WPR-2)	Lr 3	Admiral
Hobbit	(WBR-2)	Lr 3bg	Torfrida
Sappo	(WBR-3)	Lr 3ka	Haven
Maris Halberd	(WBR-4)	Lr 9	Estica
Gamin	(WBR-6)	Lr 15	
Sterna	(WBR-7)	Lr 19	
Sabre	(WBR-7)	Lr 24	
Armada	(WBR-0)		

The tests were carried out under two post-inoculation environments, a low temperature regime (10°C and 12 h. photoperiod) and a high temperature 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 summarised in Table 3.

Table 3. Classification of seedling reactions of differential cultivars to 1990 pathogen isolates

Cultivar	WBR factor	Virulence combination				Virulence frequency
Clement	1	S	R	R	R	0.66
Fundin	2*	S	S	R	S	0.98
Norman	2*	S	S	R	S	0.98
Hobbit	2*	S	S	R	S	0.98
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	S	0.04
Sabre	7*	R	R	R	R	0
Armada	0	S	S	S	S	1.00
No. of isolates		34	14	1	2	

* Temperature sensitive

Thirty four of the isolates were virulent of cv. Clement (WBR-1). Other cultivars giving a similar pattern of response were the winter wheat cvs Haven and Admiral. Cv. Hussar was resistant to isolates avirulent on cv. Clement but gave mixed susceptible or resistant reactions to isolates compatible with cv. Clement with the resistance being expressed most strongly at the higher temperature (25°C). The temperature-sensitive resistance WBR-2, present in Maris Fundin, Norman and Hobbit was effective at both temperature regimes to only one of the isolates.

The low temperature resistances of cv. Sappo (WBR-3) and Maris Halberd (WBR-4), were overcome by isolate WBRS-90-23 at 10°C, but both cultivars expressed a mixed resistant reaction to this isolate at 25°C, a reversal of the normal responses. Three isolates avirulent at 10°C gave a mixed susceptible reaction on both cultivars at 25°C and another 11 isolates gave similar patterns of response on cv. Sappo, as opposed to a predominantly resistant reaction on cv. Halberd. Isolates such as the latter group that differentiate the WBR-3 and WBR-4 resistance have only occurred rarely in the past.

Cv. Gamin (WBR-6) was susceptible to all the isolates.

Only 2 isolates, WBRS-90-51 and WBRS-90-57, were compatible with cv. Sterna (WBR-7) at both temperatures. The remaining isolates failed to overcome the temperature-sensitive resistance of cvs Sterna and Sabre at 25°C, but at 10°C a number of isolates gave a susceptible reaction, of a mainly mixed type, on both cultivars, reflecting the normal expression of this high temperature resistance.

The winter wheat cvs Torfrida and Estica were susceptible to all the 1990 isolates tested as was the spring wheat cv. Yuri although it gave a mixed susceptible reaction to some of the isolates at the higher temperature.

In the Thatcher-Lr backcross lines, which carry known specific Lr genes, Lr-1 was resistant to all the 1990 isolates to which it was tested at 25°C but was susceptible to 22 of them at 10°C (Table 4). This line displayed a similar pattern of response to that of cvs Sterns and Sabre (WBR-7) except with isolates WBRS-90-51 and WBRS-90-57 which did not induce a susceptible response in the Lr-1 line at 25°C. Seven isolates were compatible with Lr 2a at both temperatures with a more susceptible response being expressed at the lower temperature. The temperature-sensitive resistances conferred by Lr 3 and Lr 3bg were effective against all the isolates at 25°C. Three isolates were

virulent on Lr 3ka, this resistance being less fully expressed at 10°C. Lr 9 was susceptible to 25 isolates at the lower temperature but was resistant at the high temperature regime. Two isolates overcame the resistance carried by Lr 15 at 10°C, this resistance being less effective at the higher temperature with several isolates inducing a susceptible response of a mainly mixed type. The resistance expressed by Lr 19 was effective against all isolates; virulence has yet to be detected in the UK population. Lr 24 was susceptible to 2 isolates at 25°C and to 2 different isolates at 10°C.

Table 4 Reaction of Thatcher-Lr backcross lines to 1990 isolates of P. recondita at two temperatures, 10°C and 25°C

Reaction Profile		Thatcher line (Lr gene)								
10°C	25°C	Lr 1	Lr 2a	Lr 3	Lr 3bg	Lr 3ka	Lr 9	Lr 15	Lr 19	Lr 24
R/MR	R/MR	22*	11	15	33	19	21	31	48	41
R/MR	MS/S							12		2
MS/S	R/MR	22	26	12	9	9	25			2
MS/S	MS/S		7			3		2		

R = resistant; MR = mixed resistant
S = susceptible; MS = mixed susceptible
* Number of isolates

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Thirty-three winter and 7 spring wheat cultivars were sown in each of two nurseries in 1989-90. The nurseries were inoculated with one or other of the following isolates of *P.recondita*, isolated from the 1989 survey.

Isolate	Origin
WBRS-89-40 (WBV-2,6)	Cv. CWW 86/4. Cambridge
WBRS-89-47 (WBV-1,2,6)	Cv. President. Kings Lynn, Norfolk

These isolates were selected to identify cultivars carrying WBR-1 and because isolates cultured from currently grown commercial cultivars are more relevant to the monitoring of the effectiveness of resistance(s) being exploited in newly introduced wheat cultivars.

The virulence factors carried by the two isolates were identified from seedling tests but they may carry additional virulence(s) which can only be identified at the adult plant stage of growth. Assessments of percentage infection and reaction type were made on three (winter cultivars) or four (spring cultivars) occasions throughout the season.

Results

These are summarised in Table 4. Reasonable levels of disease built up on the susceptible winter wheat cultivars in both nurseries. Within the spring cultivars the rust was slower to increase, probably due to the drought conditions that occurred later in the growing season. Disease levels given in Table 4 for the spring wheat cultivars are those recorded on the final assessment date. Using data from the field nurseries, together with that from seedling test results, some of the wheat cultivars were placed into resistance groups and this can form the basis of a cultivar diversification scheme. The winter wheat cv. Haven showed a pattern of response to the two isolates similar to cv. Clement (WBR-1). Seedling tests in 1990 also showed this cultivar to carry this resistance factor. Cv. Tara, which was classified on 1989 seedling tests as carrying WBR-1, gave a pattern of response similar to that of cvs Slejpner and Dean, being susceptible only to WBV-1 isolates in seedling tests but expressing resistance at the adult plant stage of growth. Cvs Beaver and Hornet were only susceptible to isolate WBRS-89-47 (WBV-1,2,6). This conflicts with adult plant field test results in 1989 when these two cultivars were grouped with cvs Slejpner and Dean on the basis of their resistant response to a WBV-1 isolate. Uneven distribution of infection within the 1989 nurseries may have led to reduced levels of disease being recorded on these two cultivars.

Both the 1989 isolates carry WBV-2, cv. Fundin (WBR-2) being susceptible. Lower levels of infection were recorded on cvs Norman and Hobbit which are thought to carry additional resistance (Clifford et al, 1982).

In 1989 seedling tests, the spring wheat cvs Sappo (WBR-3) and Halberd (WBR-4) were resistant to both isolates, at both high and low temperature regimes. Cv. Sappo was susceptible in adult plant tests with higher levels of rust infection being recorded within the nursery inoculated with isolate WBRS-89-40. Cv. Halberd (WBR-4) was also susceptible to this isolate in field tests, suggesting either contamination of the nurseries or reduced expression of resistance at the high field temperatures. Seedling test results with 1989 isolates suggested that cv. Canon be grouped with cv. Sappo, although it appears that cv. Canon carries additional adult plant resistance, a conclusion confirmed by the current field test results and the NIAB resistance rating of 9.

Both isolates were virulent on cv. Maris Huntsman (WBR-5). Cv. Gamin (WBR-6) was resistant to both isolates although it had been susceptible to them in seedling tests. This pattern of response has been observed previously (Jones and Clifford, 1989).

Cvs Sterna and Sabre (WBR-7) were resistant as were cvs Ranger (WBR-8) and Kinsman (WBR-8?). Low levels of infection were recorded on cv. Avalon that carries the adult plant resistant factor WBR-9.

The recently introduced winter wheat cvs Apostle, Hereward, Urban and Pastiche were susceptible as seedlings to all the 1989 isolates tested. They also displayed a similar pattern of response to the field isolates in 1990, and have been grouped together with the spring wheat cv. Yuri. This cultivar was seedling susceptible to all 1990 isolates tested and showed adult plant resistance to isolates WBRS-89-40 and WBRS-89-47.

The resistances of the wheat cvs Rendezvous, Torfrida and Axona which are temperature-sensitive to some isolates in seedling tests, were effective against both isolates. The specific resistance of cv. Parade which is expressed at the adult plant stage only, was not overcome by either isolate.

The remaining winter and spring wheat cultivars were susceptible and showed a range of quantitative responses to both isolates. With a few exceptions the cultivar rankings between isolates followed a similar pattern.

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Table 5. Reactions[+] of winter and spring* wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1990

Cultivar (NIAB rating)	WBR factor	Isolates WBRS-89-40 (WBV-2,6)	WBRS-89-47 (WBV-1,2,6)
Clement	1	1	15
Apollo (6)		2	18
Hornet (6)		0.4	17
Beaver (4)		1	16
Haven (3)		1	8
Dean	1 + ?	0	Trace R
Tara		0	Trace
Slejpner (8)		0	0
Fundin	2	13	24
Hobbit		3	12
Norman		4	9
Sappo*	3	14	5
Canon* (9)	3 + ?	Trace	Trace
Halberd*	4	6	0.2
Huntsman	5	9 MS	12
Gamin	6	1 MS	2
Sabre	7	0.3 R	0
Sterna		0	0
Ranger	8	0	1
Kinsman	8?	0	0
Avalon (5)	9	5	5
Yuri*		0	0
Apostle		0	0.2
Hereward (9)		Trace	0.2
Pastiche (9)		0.2	0.1
Urban		1	3
Axona* (9)		Trace	0.1
Torfrida		Trace MS	0.1
Rendezvous		Trace	0.1
Parade		Trace	0.2
Longbow		3	7
Mercia (4)		5	11
Armada		6	10
Galahad (3)		6	11
Axial		10 MS	10
Riband (3)		12	10
Alexandria* (3)		12	12
Brock (4)		14	18
Talon (3)		14	20
Tonic* (3)		16	7

+ Mean of 3 replicates, 3 assessment dates (winter cvs)
Mean of 4 replicates, final assessment date (spring cvs)
All reaction types susceptible unless stated
MS = Mixed Susceptible; R = Resistant
( ) NIAB rating: 1 = susceptible, 9 = resistant

MILDEW OF BARLEY

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The frequencies of barley powdery mildew virulence factors corresponding to the race-specific resistances used in barley cultivars in Britain continued to be high for the resistances which are most widely utilised (BMR 1, 2, 5, 6a, 6b and 6c), and static or increasing for those more recently introduced or less widely utilised (BMR 4, 7, 8 and 10). There was no evidence of increased virulence for BMR 9 (*mlo*), which continues to provide effective resistance. The most frequent virulence phenotypes were complex, with about 70% of isolates carrying 5 or more virulence factors.

INTRODUCTION

The barley powdery mildew surveys in 1988 and 1989 (Slater *et al.* 1989, Brown *et al.* 1990) indicated that the resistance genes currently used in commercial cultivars of barley in the UK do not in general provide effective resistance to the disease. The exception was barley mildew resistance factor 9 (BMR 9), controlled by allele *mlo*.

The 1990 survey continued with the aims of:

1. Monitoring changes in the frequencies of virulences matching the mildew resistances in currently grown cultivars.

2. Determining the specific resistances in new cultivars and estimating the frequencies of common combinations of virulences for the compilation of variety diversification schemes.

Work for the barley powdery mildew survey moved to NIAB, Cambridge in 1990, and virulence testing began in July. This was too late in the season for the receipt of infected barley leaves from UKCPVS participants. The 1990 survey was carried out using samples from variety trials plots and on single colony isolates from seedlings of Golden Promise exposed on a high roof at NIAB. The source of the isolates is therefore limited, and not necessarily representative of the barley powdery mildew population in Britain.

METHODS

Isolates were derived from samples of infected leaves taken in July from variety trials plots at three sites; NIAB, Cambridge (116 isolates), Headley Hall, West Yorkshire (13 isolates), and Dunmow, Essex (19 isolates). Several samples were taken from the same cultivar at each site, making in effect only 19 samples from different cultivars at different sites. The source cultivars were; Annie (MMG 8817/5, BMRx), Blenheim,

Corniche and Prisma (BMR5,6c), Chad and Decor (BMR6c,7?), Digger (BMR10a), Hart (BMR9), Heritage (BMR10?), Klaxon (BMR4,6a,6b), Nomad (BMR4?,8), Nugget and Tyne (BMR4?,10?), Shirley (BMR4,5), Target (BMR1), and Triumph (BMR6b,6c).

Single colony isolates were taken from seedlings of Golden Promise, exposed on a high roof at NIAB, Cambridge in July and October (roof isolates). A total of 100 isolates was tested from each of these months.

All isolates were tested for virulence on the detached leaves of the differential cultivars listed in Table 1. These cultivars carry the resistances known to have been used in barley cultivars grown in the UK. However, Astrix (BMR1a,1b) did not differentiate BMV 1a from 1b, and Zephyr (BMR2a,2b) did not differentiate BMV 2a and 2b. The frequencies of these virulence factors have been very high in previous years (Slater *et al.* 1989, Brown *et al.* 1990). Virulence was determined according to the infection types of Moseman *et al.* 1965.

Table 1. *Differential cultivars used for determining virulence factors in isolates of barley powdery mildew in 1990.*

BMR Group	European code*	Resistance gene	Cultivar
0			Golden Promise
1a, 1b	Ha, Ra	*Mlh, Mlra*	Astrix
2a, 2b	We	*Mlg, Ml(CP)*	Zephyr
3	Sp	*Mla6*	Midas
4	La	*Ml(La)*	Lofa Abed
5	Ar	*Mla12*	Hassan
6a	Kw	*Mlk*	Hordeum 1063
6b	Ly	*Mla7*	Porter
6b, 6c	Ly, Ab	*Mla7, Ml(Ab)*	Triumph
5, 6c	Ar, Ab	*Mla12, Ml(Ab)*	Natasha
7	Al	*Mla1*	Tyra
6a, 8	Kw, MC	*Mla9*	Simon
9	Mlo	*mlo*	Apex
10a	Ru	*Mla13*	Digger
10b + ?	Ru, ?	*Mla13, ?*	Sherpa
6c, 10	Ab, Ru	*Ml(Ab), Mla13*	Camargue

* Jørgensen, 1987

RESULTS

Virulence Frequencies

The frequencies of BMV 1, 2, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10 amongst the leaf and roof isolates are given in Table 2. For the leaf sample, the frequencies have been expressed in two ways; in the first, all virulences from all isolates have been included irrespective of the source cultivar, and in the second, the virulences from each isolate matching the resistances of its source cultivar have been excluded. That is, only

unnecessary virulences have been considered. Since the resistance factors in Annie are not known, isolates from this cultivar have been excluded from the second presentation.

Considering only unnecessary virulences reduces the selective influence of host resistance on the frequencies of the virulence factors in the leaf sample. This is probably more representative of the mildew population in the areas from which leaf samples were taken. The frequencies of BMV 4, 5, 6c, 7, 8 and 10 are lower when only unnecessary virulences are considered, indicating selection for these virulences by the host cultivars.

BMV 3, 4, 7, 8 and 10 occurred at frequencies of about 20% in most of the samples, and the corresponding resistances may still have some effectiveness. BMV 1, 2, 5, 6a and 6b were all found at high frequencies. None of the isolates were virulent on Apex (BMR 9), including 7 isolates from Hart (BMR 9).

The limited source of the samples used in the 1990 survey means that changes from previous years in the frequencies of particular virulence factors must be viewed with caution. The frequencies of BMV 1, 2, 6a, 6b, 7 and 8 showed little change from 1989. BMV 3 may have declined slightly, probably because of the absence of BMR 3 from current cultivars (Slater *et al.* 1989). BMV 4 and 5 were also recorded at lower frequencies in 1990, but since cultivars with BMR 4 and 5 are widely grown at present this may be sampling error. BMV 10 showed an increase, corresponding to the increased acreage of Pipkin.

Table 2. *Frequency of virulence factors in isolates from infected leaves (leaf sample), and in random samples of single colony isolates formed by airborne spores (roof samples).*

Virulence factor	Frequency of virulence factors (%)			
	Leaf sample, July 1990		Roof sample July 1990	Roof sample Oct. 1990
	All data	Unnecessary virulence*		
1	64	72		
2	94	88		
3	10	11	16	17
4	39	14	22	20
5	63	41	60	59
6a	80	67	69	64
6b	61	54	79	68
6c	60	21	65	66
7	25	14	6	5
8	22	14	9	17
10	44	12	17	33
Number of isolates	146	136	100	100

* Includes virulence factors only where they were unnecessary for virulence on the host cultivar.

Complexity of Isolates

Table 3 shows the number of virulence factors carried by the mildew isolates. Most isolates were complex, with at least 69% of them in each sample carrying 5 or more virulence factors.

Table 3. *Number of virulence factors (BMV 1, 2, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10) carried by isolates of barley mildew.*

No. of BMV factors	Frequency of isolates (%) Leaf sample July 1990	Roof sample July 1990	Roof sample Oct. 1990
0	0	0	1
1	1	1	2
2	0	0	2
3	4	16	7
4	9	12	14
5	25	25	28
6	29	33	30
7	29	11	14
8	3	2	1
9	0	0	0
10	0	0	0
11	0	0	0
No. of isolates tested	146	100	100

Frequencies of Virulence Phenotypes

The frequencies of the most common virulence phenotypes defined by BMV 1, 2, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10 in the leaf and roof samples are shown in Table 4. These common phenotypes represented about 45% of the total number of isolates in each sample, with the remaining phenotypes recorded only once or twice.

The frequencies of particular phenotypes varied between the two types of sample. Phenotypes BMV1,6b,6c, BMV1,2,5,6b,6c, and BMV1,2,5,6a,6b,6c were the commonest phenotypes in the roof samples, but were relatively infrequent in the leaf sample. The most frequent phenotype in the leaf sample, BMV 1,2,6a,6b,6c,8,10 was relatively infrequent in the roof samples.

Several of the most frequent phenotypes were those with the greatest number of virulence factors. The commonest phenotype in the leaf sample (BMV1,2,6a,6b,6c,8,10) was also the most common in 1988 and 1989 (Slater *et al.* 1989, Brown *et al.* 1990). Most of the common phenotypes are virulent on cultivars in more than one diversification group, but the phenotype BMV1,2,4,5,6a,6b,6c,8,10, detected for the first time last year (Brown *et al.* 1990) and avirulent only on cultivars with BMR 3 or 7, was found in only one isolate.

Table 4. *Frequencies of the most common barley mildew virulence phenotypes, defined by BMV 1, 2, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10.*

BMV phenotype	Frequency of virulence phenotype (%) Leaf sample July 1990	Roof sample July 1990	Roof sample Oct. 1990
2, 5, 6a, 6c	6	0	0
1, 2, 5, 6a, 6c	4	2	0
1, 2, 4, 5, 6a, 6c	6	2	3
1, 6b, 6c	0	11	2
1, 2, 5, 6b, 6c	1	5	8
1, 2, 5, 6a, 6b, 6c	2	18	8
2, 5, 6b, 6c, 7	5	0	0
1, 2, 4, 5, 6a, 6b, 10	6	0	0
1, 2, 6a, 6b, 6c, 10	6	4	5
1, 2, 6a, 6b, 8, 10	3	1	8
1, 2, 6a, 6b, 6c, 8, 10	12	2	3
Total no. of phenotypes	58	51	50
No. of isolates tested	146	100	100

The complexity of the common virulence phenotypes increases the difficulty of maintaining a practical variety diversification scheme for barley. The following virulence combinations which match the resistances in two diversification groups (in addition to group 0) were recorded at high frequencies:

BMR 2, 4	and BMR 5	(Diversification groups 3 and 5)
BMR 6b, 6c	and BMR 8	(Diversification groups 6 and 8)
BMR 6b, 6c	and BMR 10	(Diversification groups 6 and 4)
BMR 8	and BMR 10	(Diversification groups 8 and 4)

Given the limited source of the isolates used in this year's survey, these data are an inadequate basis for recommendations of changes to the diversification scheme. A high risk of the spread of mildew between cultivars in diversification groups 4 and 8 is already indicated.

Resistance Factors in New Cultivars

The resistance factors in cultivars currently included in the barley mildew variety diversification scheme are given in Table 5.

Heritage was originally thought to have BMR 9 because of its parentage, but the results of detached leaf tests to determine the virulence of isolates from Heritage suggested that it has BMR 10. Further tests using differential mildew isolates confirmed this.

Additional tests on Shirley suggest that it has BMR4,5.

Table 5. *Mildew resistance factors of cultivars in the Barley Mildew Diversification Scheme.*

BMR 0		**BMR 8**		**BMR 4,6b**	
Clarine	(W)	Manitou	(W)	Doublet	(S)
Gaulois	(W)	Poacher	(W)		
Halcyon	(W)			**BMR 4,6a,6b**	
Maya	(W)	**BMR 9**		Klaxon	(S)
Pastoral	(W)	Alexis	(S)		
Paris	(W)	Atem	(S)	**BMR 4,6a,7**	
Plaisant	(W)	Hart	(S)	Regatta	(S)
Posaune	(W)	Redstart ?	(S)		
Shire	(W)			**BMR 5,6c**	
Sprite	(W)	**BMR 10**		Blenheim	(S)
Target	(W)	Pipkin	(W)	Corniche	(S)
G. Promise	(S)	Digger	(S)	Natasha	(S)
		Heritage ?	(S)	Prisma	(S)
BMR 1		Sherpa (+?)	(S)		
Finesse	(W)	Tyne (+4?)	(S)	**BMR 6b,6c**	
Igri	(W)			Triumph	(S)
		BMR 1,2,3			
BMR 2		Kira	(W)	**BMR 6c,7?**	
Fighter	(W)	Torrent	(W)	Chad	(S)
Frolic	(W)			Decor	(S)
Gypsy	(W)	**BMR 1,2,5**			
Magie	(W)	Puffin	(W)	**BMR 6c, 8**	
Melusine	(W)			Nomad	(S)
Mimosa	(W)	**BMR 2,4**			
Panda	(W)	Golf	(S)	**BMR 6c,10**	
				Camargue	(S)
BMR 2,6b		**BMR 4,5**			
Volga	(S)	Shirley	(S)	**UNKNOWN**	
				Annie	(S)
BMR 5		**BMR 4,6a**		Forester	(S)
Sarah	(W)	Oboe	(S)	Nugget (4?,10?)	(S)
Waveney	(W)				
BMR 6b					
Marinka	(W)				

(W) winter barley, (S) spring barley

CONCLUSIONS

The results of the 1990 barley powdery mildew survey follow the trends identified in previous years. That is:

1. High frequencies of virulence factors matching specific resistances which have been used for a number of years in barley cultivars grown in Britain.

2. Increasing frequencies of virulence factors matching more recently introduced resistance factors.

3. Increasing complexity of the barley powdery mildew population.

BMR 3, 4, 7, 8 and 10 may still have some effectiveness in controlling mildew, particularly combinations of BMR 4 (*Ml(La)*) with BMR 3, 7, 8 or 10 (*Mla6, Mla1, Mla9* and *Mla13* respectively). However, it is very likely that the mildew population will adapt rapidly to any new combinations. BMR 9 remains effective in Britain.

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MILDEW OF BARLEY IN NORTHERN IRELAND

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Twenty-two isolates were tested during the year and their distribution accross varieties is indicated in Table 1.

Table 1. Source of mildew isolates tested in 1990

BMR group	Isolate source	No. isolates
0	Golden Promise	6
9?	Dandy	1
10	Digger	4
4 + 6a + 6b	Klaxon	6
	Escort	1
4 + 6a + 7	Regatta	1
4 + 10	Tyne	1
5 + 6c	Blenheim	2
	Prisma	3
6b + 6c	Triumph	2

The cultivars used for the testing of virulences of the isolates are shown in Table 2.

Table 2. Test cultivars for the detection of virulence groups.

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

The method of scoring was changed to that outlined by Brown *et al* (1989) although the data given below are from plants growing in pots rather than from detached leaves. The percentage of the various virulence groups on all varieties is given in Table 3, which also contains a comparison with the earlier scoring system for N. Ireland from the previous year. Some figures for Britain, also from the previous year, but using the new system

are also included.

Table 3. Frequencies of virulence alleles from isolates collected from infected leaves in 1990.

Virulence	No.	%	Pathogenicity value in N.I. in 1989	Virulence % in GB 1989	1990
2	9/21	43	65	98	
3	9/22	41	35	23	11
4	6/22	27	53	62	14
5	10/22	46	77	83	41
6a + 6b	10/21	48	42		
6b + 6c	7/21	33	38		
7	4/20	20	31	19	14
8	6/22	27	44	19	14
3 + 4	14/21	67	32		
4 + 5	6/22	27	32		
4 + 6a	11/22	50	37		
4 + 6a + 6b	13/22	59	43		
4 + 9	0/22	0	5		
10	3/22	14		8	12

There are some correlations between the figures, *e.g.* BMV group 4 + 9 was 0 in 1990 and had an exceptionally low pathogenicity value in 1989. Similarly the frequency of BMV group 10 was low both in N. Ireland in 1990 and in Britain in 1989 and 1990. However, there are also some differences. BMV group 3, which was previously lower than groups 2 and 4, is now similar to 2 and higher than 4. Similarly BMV group 3 + 4 has a high relative value compared with those of recent seasons. This does not seem to reflect any trend in cultivar preference, the five most popular cultivars in N. Ireland being, at present, Escort, Klaxon (4 + 6a + b), Atem (4 + 9), Digger (10) and Regatta (4 + 6a + 7). Some of the unexplained variation may be attributable to unfamiliarity with the new scoring system and problems in estimating "virulence" as against "avirulence". The provision of a new, clearer key should improve the situation in 1991.

Although tests on the effectiveness of Baytan seed-treatment were continued in 1990, results were very variable and are not included in this report.

REFERENCE

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YELLOW RUST OF BARLEY

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One isolate possessing BYV1 was received during 1990

INTRODUCTION

The specific resistances (BYR factors) identified in barley cultivars to date, differential cultivars possessing each resistance and the year of first detection of corresponding virulence in the UK population of P. striiformis are given in Table 1.

Table 1 Resistance factors to Puccinia striiformis and differential cultivars

BYR Factor	Type*	Differential Cultivars	BYV detected
BYR 1	O	Astrix, Atem	1960
BYR 2	O	Bigo, Varunda	)1972-1975
	S	Mazurka	)
BYR 3	?S	Triumph	1983

* O = Overall, S = Seedling. Overall resistances are effective at all growth stages, seedling resistances are ineffective at adult plant growth stages.

METHODS

The methods used for seedling tests were similar to those described for wheat yellow rust by Priestley, Bayles and Thomas (1984).

Seedling tests with 1990 isolates

One sample of yellow rust from a spring barley cultivar from Northumberland was received and cultured.

RESULTS

Virulence frequencies for 1977-1990 are shown in Table 2.

Table 2 Virulence factor frequency (%)

	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90
BYV 1	100	98	100	100	100	100	100	100	-	-	100	-	100	100
BYV 2	18	32	0	54	81	96	87	100	-	-	100	-	100	0
BYV 3≠	-	-	-	-	-	-	17	86	-	-	22	-	75	0
Number of isolates	27	44	1	56	52	25	30	7	0	0	9	0	4	1

≠ Not included in tests before 1983.

The 1990 isolate was virulent on the BYV1 differentials Astrix and Atem.

REFERENCE

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BROWN RUST OF BARLEY

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The high incidence of barley brown rust in 1990 was reflected in a large number of samples being received. Three previously identified combinations were detected from the isolates tested. Virulence to cv. Triumph was again at a reduced frequency. Contamination of the winter and spring barley field isolation nurseries with Triumph-virulent pathotypes rendered interpretation of the results difficult. The winter barley cultivars displayed a range of quantitative responses, with cv. Puffin showing good levels of resistance. The newly introduced spring barley cvs Tyne, MMG 8817/5, Forester and Dean expressed a similar pattern of response to the pathotypes. Cvs Redstart and Chad carry resistance effective against Triumph-virulent isolates.

GLASSHOUSE SEEDLING TEST WITH 1990 ISOLATES

Two hundred and sixty-six samples of barley brown rust were received reflecting the high incidence of this disease in 1990. This number included 187 sent from the ADAS Cereal Disease Survey that identified barley brown rust as the most prevalent and severe barley disease of 1990 (Polley, pers. comm.). Two hundred and fifty-six of the samples were from 33 winter barley cultivars, with only 10 samples coming from spring barleys. The samples received were from 6 ADAS regions of England and Wales (Table 1).

Table 1. Geographical location of 1990 barley brown rust samples

Location	Number of samples
ENGLAND (ADAS region)	
East	75
West central	38
East central	38
South west	35
South	31
North	27
WALES	19
Unknown	3

The large number of samples prevented the culture and testing of each one, 49 isolates of *Puccinia hordei* having been tested on the standard set of 10 differential cultivars (Table 2).

Table 2. 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
C.I. 1243	9	Pa_9	9
Triumph	10	$Pa_?$	10

Results

No new virulences or virulence combinations were identified from the isolates tested. The virulence combinations identified and their frequencies compared with the previous 3 years are given in Table 3.

Table 3. Races and their frequencies identified from the 1990 isolates compared with the previous three years

Octal designation	BRV factors	Frequency 1987	1988	1989	1990
1673	1,2,4,5,6,8,9,10	0.54	0.27	0.47	0.49
1653	1,2,4,6,8,9,10	0.30	0.57	0.18	0.12
673	1,2,4,5,6,8,9	0.12	0.16	0.35	0.39
1657	1,2,3,4,6,8,9,10	0.04	0	0	0
Number of isolates		97	60	73	49

The frequency of virulence to the differential cv. Triumph (BBR-10) was again at a reduced level in 1990 (0.61), continuing the trend of recent years (Table 4). Virulence to this cultivar showed a rapid increase in frequency between 1981 and 1984 (Jones & Clifford, 1985) when cv. Triumph and its derivatives became more widely grown.

Table 4. Frequency of virulence to cv. Triumph

UK CPVS Year	Frequency	No. of samples tested
1987	0.88	97
1988	0.84	60
1989	0.65	73
1990	0.61	49

Virulence to the differential cvs Ribari (BBR-3) and Cebada Capa (BBR-7) was not detected in 1990.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Thirty-one winter and 27 spring barley cultivars were sown in each of two nurseries. One was inoculated with race octal 1653 and the other with race octal 677. A third nursery, sown with spring barley cultivars only, was inoculated with race octal 11.

Octal race	BRV-factors
1653	1,2,4,6,8,9,10
677	1,2,3,4,5,6,8,9
11	1,4

Results

High levels of disease built up on the susceptible winter barley cultivars early in the season. Brown rust sampled from the spreader cultivar within the two nurseries during late spring identified contamination with race octal 1673. The winter barley cultivars displayed a range of quantitative responses within both nurseries with cultivar rankings between nurseries following a similar pattern (Table 5). Cv. Puffin again expressed good levels of resistance.

A group of 10 cultivars, namely Target, Clarine, Gypsy, Sarah, Fighter, Manitou, Poacher, Shire, Paris and UN1273B were sown later in the autumn. Reduced levels of rust infection on several of these cultivars, particularly within the nursery inoculated with octal race 1653, should be interpreted with caution.

High levels of naturally occurring inoculum in recent years has resulted in contamination of the spring barley field isolation nurseries with Triumph-virulent pathotypes. Placing the cultivars into groups on the basis of their

specific resistances is thus made difficult, particularly for the recently introduced cultivars where data is limited. Previous years' results have enabled many of the older cultivars to be placed into specific resistance groups, whilst the newer cultivars have been grouped on the basis of similarities in their patterns of response to a Triumph virulent isolate (Table 6).

Cvs Tyne, MMG 8817/5, Forester and Decor showed similar mixed reaction types. The resistance of cvs Redstart and Chad was effective against the pathotypes as was the adult plant resistance of cv. Corniche.

REFERENCES

Jones, E.R.L. and Clifford, B.C. (1985). Brown rust of barley. *UK Cereal Pathogen Virulence Survey 1984 Annual Report*, pp. 58-62.

Table 5. Percent infection* of winter barley cultivars with specific isolates of P. hordei Otth in field isolation nurseries in 1990

Winter cultivar (NIAB rating)	Race octal 1653 BRV- 1,2,4,6,8,9,10	Race octal 677 BRV- 1,2,3,4,5,6,8,9
Pipkin (5)	37	41
Torrent (4)	34	39
Waveney	30	38
Gerbel	24	36
Pirate	26	35
Panda (5)	29	34
Clarine (4)	21	34
Magie (5)	28	31
Marinka (6)	28	31
Masto	26	31
Posaune (6)	25	31
Vixen	29	30
UN 1273 B	18	30
Pastoral (6)	27	29
Igri (6)	25	29
Halcyon (6)	25	29
Sarah	19	29
Paris	19	28
Manitou (5)	17	28
Poacher	12	28
Melusine (5)	26	27
Mimosa	26	27
Kira (6)	22	27
Frolic (6)	25	26
Finesse	21	26
Gaulois (6)	19	26
Shire	15	25
Gypsy (7)	19	24
Target (5)	15	24
Fighter (7)	7	14
Puffin (8)	3 MS	8

* Mean 4 replicates at 2 assessment dates
( ) NIAB rating: 1 = susceptible, 9 = resistant
All reaction types susceptible unless stated
MS = mixed susceptible;

Table 6. Percent infection* of spring barley cultivars with a Triumph virulent isolate of *P. hordei Otth* in a field isolation nursery

Spring cultivar (NIAB rating)	Race octal 1653 BRV- 1,2,4,6,8,9,10
Group I (BBR-0)	
Golden Promise	34
Midas	35
Group II (BBR-10)	
Triumph (4)	14
Natasha (5)	20
Prisma (4)	20
Doublet (5)	23
Blenheim (4)	26
Hart (4)	25
Klaxon (5)	24
Regatta	22
Armelle	14
Nomad (6)	22
Nugget (7)	21
Heritage	18
Shirley (6)	15
Group III (BBR-5)	
Vada	14
Atem (5)	29
Digger (4)	25
Group IV (BBR-3)	
Simon	0
Alexis (7)	7 MS
Group V (BBR-10+?)	
Corniche (8)	2
Tyne	14 MS
MMG 8817/5	14 MS
Forester (8)	10 MS
Decor (6)	10 MS
Redstart	20 R
Chad (6)	7 MR

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

RHYNCHOSPORIUM OF BARLEY

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The frequency of virulence to BRR-5 present in cv. Pipkin showed a further increase in 1990. Three isolates were virulent on the differential cv. Osiris, virulence to which has previously been detected in one naturally infected sample only, in 1985. Some of the 1990 *Rhynchosporium* isolates gave increased virulence to cv. Digger which has previously shown high levels of resistance in seedling and adult plant tests. This spring barley cultivar was resistant to race octal 0 in an adult plant field nursery as were cvs Armelle and Osiris which carry specific resistances. The remaining spring barley cultivars displayed a range of quantitative responses to this race.

SEEDLING TESTS WITH 1990 ISOLATES

Only 18 samples of barley leaf blotch were received in 1990, the dry spring and summer not being conducive to the spread of this splash-borne pathogen. Fourteen of the samples were from the winter barley cvs Pipkin (5), Igri (3), Marinka (3), Otter, Sarah and Vixen. The remainder were from spring cultivars. The samples were from several locations (Table 1).

Table 1 Geographic origin of *Rhynchosporium* samples received in 1990

Geographic origin	Number of samples
England (ADAS region)	
East	7
South-West	7
South	1
West-Central	1
Wales	1
Unknown	1
Total	18

Thirteen isolates were successfully increased and tested on a set of differential cultivars together with additional winter and spring cultivars. Test cultivars and their resistance factors are given in Table 2.

Table 2. Differential test cultivars for *Rhynchosporium secalis*

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

Results

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

Table 3. Virulence factor combinations identified from the 1990 survey

No. of isolates	Differential cultivars in fixed linear order							Octal vir. des.
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
4	0	0	0	1	1	0	0	14
3	1	0	0	1	1	1	1	117
2	1	1	1	1	1	0	0	174
1	1	0	0	1	1	0	0	114
1	0	0	0	0	0	0	0	0
1	1	1	1	0	1	0	0	164
1	0	0	1	0	1	0	0	24
Virulence frequency								
1990	0.54	0.23	0.30	0.76	0.92	0.23	0.23	
1989	0.54	0.08	0.23	0.92	0.92	0.62	0.62	
1988	0.81	0	0	0.98	0.98	0.19	0.19	

1 = susceptible, 0 = resistant

Three new races were identified in 1990, with virulence to the differential cv. La Mesita (BRR-5) being common to the three. The frequency of this virulence appears to be increasing (Table 3). Race octal 24 and race octal 164 were each identified in one isolate with race octal 174 being identified in two. The 4 isolates were cultured from infected leaf samples of the winter barley cv. Pipkin which carries the same resistance gene, Rh^4, as La Mesita. Three of these isolates were also virulent on the differential cv. Osiris (BRR-6), virulence to which has previously been detected only in one naturally infected sample in 1985. Cv. Digger was included in 1990 seedling tests as it has shown high levels of resistance in previous years' seedling and adult plant field tests. Previously, only low levels of infection (less than 2%) have been produced on seedlings of cv. Digger by a few isolates but several of the 1990 isolates gave levels of 5% to 10% leaf area infected. Although cultivars with these infection levels in glasshouse seedling tests are generally classified as being resistant, it appears that there is some erosion of resistance that requires monitoring. To this end, cv. Digger will be included all seedling tests in 1991.

The increased frequencies of virulence to cvs Armelle (BRR-1) and Astrix (BRR-2) found in 1989 were not continued into 1990, values returning to 1988 levels. Such fluctuations between years are to be expected when data are from such low sample numbers.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Thirty-four winter and 28 spring barley cultivars were sown in each of 2 nurseries in the 1989-90 season. The nurseries were inoculated with one or other of the following isolates.

UK CPVS Code	Virulence characteristics	Octal designation
Rs-85-50	BRV-1,2,3,4,5,6	77
Rs-90-18	BRV-0	0

The nursery inoculated with isolate Rs-90-18 was grown alongside a *Rhynchosporium* disease nursery used to screen barley material and which is infected naturally. Leaf samples taken from the nursery during the season were tested on seedlings of the set of differential cultivars. The isolate was identified as race octal 0 although a low level of infection was recorded on cv. Athene (BRR-3).

Results

The dry conditions in the spring and early summer resulted in the failure of disease to spread within the winter and spring barley nurseries inoculated with isolate BRS-85-50, although infection of seedlings of the susceptible winter cultivars had been achieved early in the season. Disease developed within the nursery infected naturally with race octal 0, the location of this nursery being more conducive to the spread of *Rhynchosporium*. Low levels of infection were recorded on the winter barleys with only cvs Vixen (2.5%), Sarah (2.5%), Panda (2.0%), Halcyon (1.5%), Poacher (1.5%) and Waveney (1.2%) displaying levels in excess of 1% leaf area infected. Reasonable infection of the spring cultivars revealed quantitative differences in susceptibility to race octal 0 (Table 4). Cvs Armelle (BRR-1), Osiris (BRR-6) and Digger (BRR-?) were resistant to isolate Rs-89-18 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* of spring barley cultivars in *Rhynchosporium* isolation nurseries in 1990

Cultivar (NIAB rating)	Rs-90-18 (BRV-0)
Forester (3)	15
Alexis (3)	10
Chad (5)	8
Atem (5)	8
Hart (4)	7
Prisma (3)	6
Doublet (3)	5
Golden Promise	5
MMG 8817/5	5
Corniche (3)	4
Midas	4
Natasha (4)	4
Nomad (4)	4
Shirley (4)	4
Klaxon (6)	3
Nugget (5)	3
Regatta	3
Decor (5)	3
Tyne	3
Heritage	3
Blenheim (3)	2
Triumph (4)	2
Redstart	2
Proctor	2
La Mesita	1
Armelle	0.2
Digger (9)	0.2
Osiris	0.05

* Mean of 4 replicates, 2 assessment dates
( ) NIAB rating: 1 = Susceptible, 9 = Resistant

NET BLOTCH OF BARLEY

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The three leaf samples of net blotch received in 1990 were successfully tested on seedlings of the differential cultivars. Two were identified as being widely virulent. Disease was slow to build up in the adult plant field nursery, particularly within the winter cultivars. Slightly higher levels of infection within the spring barley cultivars identified the newly introduced cultivars Heritage, Decor and Tyne as being the most susceptible to the artificially introduced isolate.

GLASSHOUSE SEEDLING TESTS WITH 1990 ISOLATES

Only three samples of net blotch were received. Spore suspensions, prepared by soaking the infected leaves in water for 48 hrs, were inoculated onto seedlings of the 13 differential cultivars (Clifford, del Buono and Jones, 1984). Cv. Marinka was also included in the tests.

The virulences identified occurred in different combinations in the three isolates (Table 1). Two of the isolates BNS-90-2 and BNS-90-3 were widely virulent, carrying virulence factors compatible with 9 and 12 of the differential cultivars respectively.

Table 1. Virulence combinations identified in 1990 isolates

Sample no.	Cultivar and location of sample	Virulence combination
BNS-90-1	Target, Trerulefoot, Devon	6,8,9,11,12
BNS-90-2	Sp. barley breeding line, Trumpington, Camb.	1,2,4,5,6,8,9,11,12
BNS-90-3	Tintern, Aberystwyth, Dyfed	1,2,3,4,5,6,7,8,9,11,12,13

The low number of samples prevents comparison of the frequencies of virulence in 1990 with previous years. Virulences compatible with the resistance factors in the 13 differential cultivars have been identified previously, although some have remained at a low frequency. The virulence combination of isolate BNS-90-3 is the most complex identified in the UK with only Code 65 giving a resistant reaction. The winter cv. Marinka was also susceptible to this isolate.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Thirty one winter and 24 spring barley cultivars were sown in a single nursery in 1989-90. The nursery was inoculated with a spore suspension prepared from infected leaf material harvested in the autumn of 1989 from volunteer barley plants. Subsequent seedling tests identified virulence factors 2, 4, 5, 8, 9, 10, 11, 12.

Results

Disease established within the winter nursery early in the season, but as in previous years was slow to increase. One assessment of percentage levels of infection was made towards the end of the season although only low levels of disease were recorded. The very low levels of infection on the winter test cultivars is partly due to the environment but also reflects the levels of resistance previously detected in many winter cultivars.

Slightly higher levels of net blotch infection were achieved within the spring barley cultivars, assessments being made on three dates: 22nd June, 2nd July and 10th July (Table 2). They displayed a range of quantitative responses, with some of the new spring barley cultivars under test, Heritage, Decor and Tyne being the most susceptible. The spring barley Golden Promise was heavily infected with barley leaf stripe (*Pyrenophora graminea*) and so no assessment of net blotch infection was possible.

REFERENCES

Clifford, B.C., del Buono, R. and Jones, E.R.L. (1984). Net blotch of Barley. *UK Cereal Pathogen Virulence Survey 1983 Annual Report*, pp. 64-69.

Table 2. Percentage infection* on spring barley cultivars inoculated with *Pyrenophera teres* in a field nursery in 1990.

Cultivar	Field isolate Virulence factors 2,4,5,8,9,10,11,12
Heritage	2.0
Decor	2.0
Tyne	1.5
Prisma	1.5
Alexis	1.2
Blenheim	1.0
Doublet	1.0
Triumph	0.8
Klaxon	0.6
Corniche	0.5
Atem	0.5
Digger	0.4
Hart	0.4
Midas	0.4
Nomad	0.3
Natasha	0.3
Forester	0.3
Chad	0.3
MMG 8817/5	0.3
Shirley	0.3
Nugget	0.3
Redstart	0.2
Regatta	0
Golden Promise#	-
Spreader (Mixture)	4.0

* Mean of 4 replicates, 3 assessment dates.
# No assessment, heavily infected with barley leaf stripe.

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

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Of 77 infected samples received in 1990, 73% contained barley yellow mosaic virus (BaYMV) and 34% barley mild mosaic virus (BaMMV). As in previous years, BaMMV was more frequent on malting cultivars (Maris Otter, Halcyon and Pipkin) whereas BaYMV predominated amongst cultivars used for feed. Two new outbreaks of BaYMV were reported from cultivars previously regarded as immune.

INTRODUCTION

The survey, begun in 1987, aims to determine the distribution and relative frequency of the two mosaic viruses on winter barley and to detect regional or cultivar differences. Barley yellow mosaic virus (BaYMV) is difficult to transmit mechanically and the optimum temperature for symptoms is below 15°C. Barley mild mosaic virus (BaMMV) is readily transmitted mechanically and can express symptoms at higher temperatures than BaYMV; it was previously regarded as a strain of BaYMV (-M strain in Germany, "Streatley" strain in the UK) but the two viruses are not serologically related and are now regarded as distinct. The viruses cause similar symptoms, are both transmitted by the root infecting fungus *Polymyxa graminis*, and can occur together in the same plant.

METHODS

Samples with symptoms were received during winter and spring (9 January to 6 June), mostly from ADAS regional offices. Leaves were tested serologically, usually by enzyme-linked immunosorbent assay (ELISA), for the presence of both viruses.

RESULTS AND DISCUSSION

Seventy-seven positive samples were received in 1990 but the cultivar was known only for 50 of them. The samples received do not constitute a random survey of disease outbreaks and the results must therefore be treated with some caution. BaYMV (73% samples) was generally more frequent than BaMMV (34% samples), although BaMMV predominated on the malting cultivars Maris Otter, Halcyon and Pipkin, and a small number of samples contained both viruses (Table 1). These results are similar to previous years.

Two new outbreaks of BaYMV occurred on cultivars previously regarded as immune to both viruses (Torrent and Gaulois). There have been a total of six such reports in the UK since 1988 and they presumably represent one or more distinct races of the virus able to overcome the single, recessive, resistance gene shared by all the "resistant" European barley cultivars. Many more such outbreaks have been reported from Germany and France and there is a concern that a similar situation will develop in the UK. This is perhaps more likely to arise if winter temperatures return to more normal (lower) values than in previous years as the disease is usually more severe in colder winters. Japanese experience suggests that races of the virus with different specific virulences may be expected but there is no rapid method for diagnosis of the variants and the relationship between European and Japanese races has not been determined.

Table 1. Mosaic virus samples from 1990, classified by cultivar

	BaYMV alone	BaMMV alone	Both viruses
Malting cultivars			
Maris Otter	0	2	0
Halcyon	1	2	0
Pipkin	0	2	1
Feed cultivars			
Igri	3	1	0
Panda	2	0	0
Plaisant	1	2	2
Magie	9	5	1
Marinka	5	2	0
Frolic	2	0	0
Kira	3	0	0
Puffin	0	1	0
Fighter	1	0	0
Torrent*	1	0	0
Gaulois*	1	0	0
Total	29	17	4

*, immune to the common strain of BaYMV

MILDEW OF OATS

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Twenty six samples of oat mildew were received in 1990 and from these 15 isolates were successfully cultured and tested on seedlings of the differential cultivars. The widely virulent race 5 (OMV 1,2,3) was identified from 66% of the isolates. Virulence to the resistance derived from *Avena barbata* (OMV 4) was found in 5 isolates, all samples from oat breeding nurseries at the Welsh Plant Breeding Station. Races 2 (OMV 1), 3 (OMV 1,2) and 4 (OMV 1,3) were not detected.

SEEDLING TESTS WITH 1990 ISOLATES

Twenty six samples of *Erysiphe graminis avenae* were received in 1990 from a range of winter (7 samples) and spring oat (19 samples) cultivars. Isolates were successfully cultured from 15 of the infected leaf samples, and tested on a set of differential cultivars.

Results

Details of the mildew samples tested are given in Table 1. The frequency of occurrence of the various virulences detected in 1990 compared with previous years are given in Table 2.

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

Locations	Cultivars	Virulences (OMV)
ENGLAND (ADAS) Region		
East		
Wye, Kent	Image, Solva, Kynon, Aintree	1,2,3
North		
Cockle Park, Northumberland	Dula	1,2,3
WALES		
Welshpool, Powys	Aintree	1,2,3
Morfa Mawr, Dyfed	Dula, Keeper, Rollo	1,2,3,4
	Adamo, Breeding line Sang	1,2,4
WPBS, Dyfed	Mirabel	1,2,3,4
Swansea, W. Glamorgan	Solva	1,2,3
SCOTLAND		
SCRI, Dundee	Dula	1,2,3
Kelso	Dula	1,2,3

Table 2. Virulence group frequencies identified from samples received in 1990 compared with years since 1978

Virulence Group	Race	Frequency (% total) 1978	1980	1982	1984	1986	1988	1990	No. of isolates in 1990
OMV 1	2	3	0	0	0	0	0	0	0
1,2	3	42	51	39	32	31	32	0	0
1,3	4	3	3	4	2	0	0	0	0
1,2,3	5	52	41	43	64	63	68	66	10
1,2,4	6	0	3	0	0	0	0	7	1
1,2,3,4	7	0	2	14	2	6	0	27	4
No. of isolates tested		33	63	28	41	16	34	15	

Race 5 (OMV 1,2,3) continues to predominate with a frequency of 66%. Race 3 (OMV 1,2) which has declined in recent years was not identified from any of the samples, although one isolate cultured from cv. Sang combined OMV 1,2 with OMV 4. This isolate, race 6, is able to overcome the resistance derived from *Avena barbata*, virulence to which has been more frequent in combination with the more complex OMV 1,2,3 as race 7. This increase in race 7 in 1989 (15%) and 1990 (27%) should be interpreted with caution as all the isolates identified were sampled from oat breeding nurseries at the Welsh Plant Breeding Station where breeding lines incorporating this resistance are grown.

CROWN RUST OF OATS

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Glasshouse seedling tests identified four races of *Puccinia coronata avenae* from the thirteen samples cultured. All had been previously identified in the UK, although only one, race 251, occurs commonly.

Thirteen samples of oat crown rust were received from a range of winter and spring oat cultivars in 1990. Isolates of *Puccinia coronata avenae* were successfully cultured from each and tested on the International set of 10 differential cultivars.

Table 1. Locations and cultivars from which crown rust samples were received in 1990 with virulences identified for each sample.

Location	Cultivar	Race
ENGLAND (ADAS region)		
South-east	Kynon	236
South	Rollo	289
WALES		
West Glam.	Aintree	289
Dyfed	Rhiannon (2), Solva	289
	Kynon, Adamo	
	Valiant, Rollo, Commander, Dula	251
	Keeper	272

Four races were identified, although some of the cultures appeared to comprise a mixture of races. Each of the virulence combinations had been previously found in the UK. None of the isolates carried a combination of virulence genes compatible with more than three of the differential cultivars. All isolates were virulent on Saia and Appler (Table 2).

Table 2. Virulence spectra of races identified from the 1990 survey together with virulence frequencies (%) corresponding to each differential cultivar

Differential variety	Race				Virulence frequency (%)
	236	289	272	251	
Anthony	S	R	R	R	8
Victoria	R	R	R	R	0
Appler	S	S	S	S	100
Bond	R	R	R	S	31
Landhafer	R	R	R	R	0
Santa Fé	R	R	R	R	0
Ukraine	R	R	S	R	8
Trispernia	R	R	R	R	0
Bondvic	R	R	R	R	0
Saia	S	S	S	S	100
No. of isolates	1	7	1	4	

R = Resistant S = Susceptible

Race 289, last identified in 1977, was cultured from 7 samples received from 5 different sites in England and Wales and the commonly occurring race 251 was identified from 4 samples. These two races differ from each other only in their reaction to cv. Bond. Race 236, first detected in the UK in 1989, was again found in one sample, as was race 272 although this race had also been isolated in 1974.

Various virulences and combinations occur commonly in the UK population of *P. coronata* although common cultivated varieties are not known to carry corresponding resistances.

POTENTIAL SOURCES OF RESISTANCE OF WHEAT AND BARLEY TO POWDERY MILDEW

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Two genes, *Pm3b* (WMR3b) and *Pm17*, may currently be useful sources of mildew resistance in wheat. Six *Mla* alleles have been identified as being of value in improving resistance to barley mildew; another three genes are possible sources of resistance. *mlo* (BMR9) continues to provide effective resistance to barley mildew.

INTRODUCTION

Previous years' survey reports have shown the need for better mildew resistance in current varieties of wheat and barley (Brown *et al.* 1990a,b). In an attempt to identify potential sources of mildew resistance, a range of lines with genes which have been exposed in commercial varieties, or with possibly effective resistance genes, were grown in trials of resistance or susceptibility to powdery mildew at three locations: Crossnacreevy (nr. Belfast), Invergowrie (nr. Dundee) and Morley (Norfolk).

MATERIALS AND METHODS

Varieties used are listed in Table 1. Eleven wheat lines were kindly provided by Dr S. Leath, Raleigh, USA, and six barley lines and one wheat by Professor G. Fischbeck, Weihenstephan, Germany. Varieties were sown at each site in March 1990 as rows or tussocks of 12 seeds in three replicates in a randomised block design. Golden Promise (barley) and Cerco (wheat) were sown as mildew spreaders every third row. All barley varieties were spring types; some winter wheats in the trial were not vernalised and so did not flower; we assume that this does not affect the expression of mildew resistance. The level of mildew was scored at each site using the NIAB foliar disease assessment key (1-9 scale).

RESULTS AND DISCUSSION

In the results of the wheat trial, there were significant variety and site effects (both $p < 0.001$) and a significant variety × site interaction ($p < 0.05$). Three of the six most resistant lines, with mean scores of 2.0 or less (Table 1), carried *Pm3b* (WMR3b); the corresponding virulence is at a low frequency (Brown *et al.* 1990a). The USA variety Amigo (*Pm17*) was also resistant, as was Axona, although this has a mildew score of 6 in the NIAB Recommended List. Maris Dove (*Mld*; WMR9) was also fairly resistant (2.0). The largest contribution to the variety × site interaction was due to two varieties, Asosan (*Pm3a*; WMR3a) and Transec (*Pm7*), being comparatively much more resistant at Crossnacreevy than at Invergowrie or Morley. The virulences corresponding to resistance genes *Pm3a* and *Pm7* are frequent in England (Brown *et al.* 1990a), but virulence tests of wheat mildew from Northern Ireland have

not been carried out; we do not know, therefore, if the difference between Crossnacreevy and the other sites is due to differences in the wheat mildew population or to some other cause. The most promising resistance genes to emerge from this trial are therefore *Pm3b*, *Pm17*, and possibly *M1d*.

In the analysis of the barley data, there were large effects of variety, site and variety × site interaction ($p < 0.001$ for all three effects). Seven varieties were classified as resistant, with mean scores less than 2.0 (Table 1). These included P22, which carries *mlo* (BMR9). The remainder have resistances which have not been exploited in British cultivars, although *M1a3* has been used in German and Swedish barleys. Two varieties, P19 (*M1p*) and RS-145-39 x Kiel B (*M1a20*), were resistant at Morley, but not at Crossnacreevy or Invergowrie. At Morley, these both had very necrotic reactions to mildew. P19 is resistant to all isolates from The Cambridge Laboratory's collection which have been tested to date; the infection type (IT) was rather high, around 3. *M1a20*, carried by RS-145-39, has so far proved effective in Germany. It is possible that these resistances are effective, but that the necrotic IT, combined with high disease pressure from neighbouring spreader rows, may have made them appear susceptible in the particular conditions at Crossnacreevy and Invergowrie. P13 (*M1(1402)*) was moderately resistant (2.8); as with P19, all isolates from The Cambridge Laboratory's collection were avirulent in tests carried out so far; ITs were often high (2-3), however, and were variable both between and within isolates. *M1(1402)* may be responsible for the resistance of the Czechoslovak varieties Jarek and Kredit (Dreiseitel 1989). *M1p* and *M1(1402)* provided resistance to most single colony isolates sampled in 1989 (Brown *et al.* 1990b). *M1a3*, *M1a16*, *M1a17*, *M1a18*, *M1a19* and *M1a21* all appear to be potentially useful sources of resistance to barley mildew; *M1a20*, *M1p* and *M1(1402)* may be useful, but their ITs may make it difficult to select for resistance in ear rows or small plots.

No trial of this type is planned for 1991, but similar trials may be carried out in future years if information on new sources on resistance continues to be needed by cereal breeders.

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Table 1 Wheat and barley varieties tested for resistance to powdery mildew in field trials at three locations in 1990, with identified resistance genes, wheat or barley mildew resistance groups (WMR, BMR) and mildew scores following the NIAB foliar disease assessment key (9 = susceptible, 1 = resistant).

Wheat	Gene	WMR	Score[1]	Barley	Gene	BMR	Score[1]
TP114	*Pm6*	6	5.0 a	P14[3]	*Mlra*	1b	5.6 a
Kavkas	*Pm8*	7	4.3 ab	P10[3]	*Mla12*	5	5.4 a
Hope	*Pm5*[2]	5	4.2 ab	P24[3]	*Mlh*	1a	5.4 a
Khapli	*Pm4a*	4a	3.9 abc	P03[3]	*Mla6*	3	5.3 a
Ulka	*Pm2*	2	3.9 abc	P21[3]	*Mlg,Ml(CP)*	2	5.2 ab
Transec	*Pm7*		3.6 bcd	P12[3]	*Mlc*		5.1 abc
Axminster	*Pm1*	1	3.4 bcde	P17[3]	*Mlk*	6a	5.1 abc
Brock	*Pm2,?*	2,Talent	3.3 bcde	Pallas	*Mla8*	0	5.0 abc
Mephisto	*Pm1,Pm2,Pm9*	1,2	3.2 bcde	P23[3]	*Ml(La)*	4	4.9 abc
Asosan	*Pm3a*	3a	2.9 bcdef	P20[3]	*Mlat*		4.8 abc
Mercia	*Mli*[2]	8	2.8 cdef	P04B[3]	*Mla7*	6b	4.7 abc
Broom	*Pm5,Mli,?*[2]	5,8,?	2.4 defg	Triumph	*Mla7,Ml(Ab)*	6b,c	4.6 abcd
Michigan Amber	*Pm(MA)*		2.3 defgh	P08B[3]	*Mla9*	8	4.2 abcd
Sonora	*Pm3c*	3c	2.1 efghi	P01[3]	*Mla1*	7	3.8 bcde
Maris Dove	*Mld*	9	2.0 efghi	P11[3]	*Mla13*	10	3.7 cde
Chul	*Pm3b*	3b	1.8 fghi	RS-145-39 x Kiel B[4]	*Mla20*		3.3 de
Florida 301H6	*Pm3b*	3b	1.7 fghi	P19[3]	*Mlp*		2.9 ef
Amigo	*Pm17*		1.5 ghi	P13[3]	*Ml(1402)*		2.8 fg
Axona		Axona	1.3 hi	D x 1B-54B[4]	*Mla16*		1.7 gh
Florida 302	*Pm3b*	3b	1.1 i	P02[3]	*Mla3*		1.7 gh
				P22[3]	*mlo*	9	1.6 gh
				RS-20-1 x Kiel B[4]	*Mla18*		1.6 gh
				RS-170-47 x Kiel B[4]	*Mla17*		1.6 gh
				D x 1B-152B[4]	*Mla21*		1.4 gh
				D x 1B-86B[4]	*Mla19*		1.0 h

[1] Scores followed by the same letter are not significantly different by Student-Newman-Keul's test ($p > 0.05$; comparisons within species). [2] *Mli* and *Pm5* may be the same allele (Heun and Fischbeck, 1987). [3] Lines developed by Kolster *et al.* (1986). [4] Lines developed by Jahoor and Fischbeck (1987).

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1991

Variety diversification schemes to rduce 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. In 1988, spring wheat varieties were 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 of wheat and mildew of barley. The scheme for mildew of wheat has been suspended, its usefulness having been severely restricted by the limited range of specific resistances in current varieties and the increasing complexity of the mildew population. However, the situation will be under constant review and the mildew scheme will be reinstated when appropriate. Wheat varieties with good resistances to mildew are available and should be grown whenever possible.

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.

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VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN BARLEY 1991

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) Select 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

DG 0
Clarine (W)
Finesse (W)
Frolic (W)
Gaulois (W)
Gypsy (W)
Halcyon (W)
Igri (W)
Magie (W)
Maya (W)
Melusine (W)
Mimosa (W)
Panda (W)
Pastoral (W)
Paris (W)
Plaisant (W)
Posaune (W)
Shire (W)
Sprite (W)
Target (W)

DG 1
Fighter (W)
Forester (S)
Annie (S)
Nugget (S)

DG 2
Alexis (S)
Atem (S)
Hart (S)
Redstart (S)

DG 3
Golf (S)

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

DG 5
Puffin (W)
Sarah (W)
Waveney (W)
Shirley (S)

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

DG 7
Chad (S)
Decor (S)

DG 8
Manitou (W)
Poacher (W)
Nomad (S)

DG 9
Doublet (S)
Klaxon (S)

DG 10
Kira (W)
Torrent (W)

DG 11
Blenheim (S)
Corniche (S)
Natasha (S)
Prisma (S)

DG 12
Camargue (S)

DG 13
Regatta (S)

Chosen DG	Companion DG													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13
0	M	+	M	M	M	M	M	M	M	M	M	M	M	M
1	+	+	+	+	+	+	+	+	+	+	+	+	+	+
2	M	+	M	+	+	+	+	+	+	+	+	+	+	+
3	M	+	+	M	+	+	+	+	M	M	+	+	+	M
4	M	+	+	+	M	+	+	+	M	+	+	+	M	+
5	M	+	+	+	+	M	+	+	+	+	+	M	+	+
6	M	+	+	+	+	+	M	+	+	+	+	M	M	+
7	M	+	+	+	+	+	+	M	+	+	+	+	+	M
8	M	+	+	M	M	+	+	+	M	M	+	+	+	+
9	M	+	+	M	+	+	+	+	M	M	+	+	+	M
10	M	+	+	+	+	+	+	+	+	+	M	+	+	+
11	M	+	+	+	+	M	M	+	+	+	+	M	+	+
12	M	+	+	+	M	+	M	+	+	+	+	+	M	+
13	M	+	+	M	+	+	+	M	+	M	+	+	+	M

Note: 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.

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VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST IN WHEAT 1991

Severe infections may result if yellow rust spreads between varieties which are susceptible to the same races of the pathogen. 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. The Diversification Scheme should be used to choose varieties to grow adjacent to one another.

Choosing varieties to grow together

1) Select 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
   Y = high risk of spread of yellow rust
   y = moderate risk of spread of yellow rust
4) Wherever possible choose combinations of varieties marked '+'. A combination marked 'y' is a lesser risk than one marked **'Y'**.

DG 1	**DG 1 contd**	**DG 2**	**DG 3**	**DG 4**	**DG 0**
Apostle		Apollo	Brimstone	Avalon	Alexandria
Axial	Canon (S)	Beaver	Longbow	Galahad	
Hereward	Tonic (S)	Dean	Norman		
Mercia	Yuri (S)	Foreman	Riband		
Parade		Fortress	Urban	**DG 6**	
Pastiche		Haven	Axona (S)		
Rendezvous		Hornet		Brock	
Talon		Slejpner			
Tara					
Torfrida					

Chosen DG	**Companion DG** 1	2	3	4	6	0
1	+	+	+	+	+	+
2	+	**Y**	y	y	+	**Y**
3	+	y	**Y**	y	y	**Y**
4	+	y	y	**Y**	y	**Y**
6	+	+	y	y	**Y**	**Y**
0	+	**Y**	**Y**	**Y**	**Y**	**Y**

Note: Varieties in DG 1 have good resistance to yellow rust 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 yellow rust spreading from any variety and therefore do not contribute to diversification.