U.K. CEREAL PATHOGEN VIRULENCE SURVEY

1991 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 Environmental Research, 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 static seedling 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 wheat and 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 resistance and specific virulence

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 resistance are classified as RO and isolates lacking specific virulence are classified as VO.

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 1991

Mildew of wheat

Virulence factors corresponding to the resistance genes used most widely in winter wheat cultivars in the UK were recorded at high frequencies. Most isolates of mildew carried a combination of virulence factors enabling them to infect most of the cultivars on the recommended lists. However, many of the currently recommended cultivars have moderately effective background resistance.

Yellow rust of wheat

The frequencies of virulences WYV1, WYV2, WYV3, WYV4, WYV6 and WYV9, which correspond to the resistances most widely used in commercial cultivars, remained at a high level in 1991. Virulence for the cultivar Talon increased markedly to over 40%. For the first time, virulence was detected at the seedling stage for the cultivars Hereward, Estica and Hussar.

Brown rust of wheat

Seedling tests with the 1991 isolates of P. recondita showed that the winter wheat cultivar Zodiac carries the resistance factor WBR1 The spring wheat cultivar Baldus gave a pattern of response similar to cultivar Sappo (WBR3) to isolates in seedling and adult plant field tests. Virulence for Slejpner (WBR1 + adult plant resistance) was identified in a field nursery inoculated with isolate WBR-90-9 (WBV 1,2,6). The 'breakdown' of this resistance was confirmed in glasshouse tests where other cultivars carrying this resistance were susceptible to the same isolate. The resistance of the winter wheat cultivars Pastiche, Hereward, Torfrida, Hussar and Estica was effective against isolates used in field tests, as was that of the spring cultivars Axona and Troy.

Mildew of barley

Individual barley mildew virulence factors and combinations of virulence factors matching the specific resistances used in barley cultivars in the UK were mostly recorded at high frequencies in the 1991 survey. The combinations BMV7 (virulent on Chad), BMV6c,7 (virulent on Decor), BMV6c,8 (virulent on Nomad) and BMV4,10 (virulent on Tyne and Nugget) were recorded at the lowest frequencies. Virulence for BMR9 (mlo) was not detected, and this gene continues to provide effective resistance to mildew. The most common pathotypes carried a large number of virulence factors and would be able to infect a wide range of cultivars.

In N Ireland, isolates virulent on BMR10 increased considerably over the previous season. Tests with Baytan seed-treatment indicated a general increase in resistance with time.

Brown rust of barley

Five previously identified virulence combinations were detected amongst the 1991 isolates. Virulence for cultivar Triumph increased to 93%, reversing the trend observed in 1989 and 1990. Two isolates were identified as being the widely virulent race octal 1677, last detected in 1986. Field isolation nurseries showed that winter barley cultivars display a range of quantitative responses to two isolates. Spring barley cultivars were grouped on the basis of their responses to three isolates.

Rhynchosporium of barley

One new virulence combination, BRV 1,2,3,7 (race octal 107), was identified from the 50 isolates of Rhynchosporium secalis tested on seedlings in 1991. The resistance of the spring barley cultivar Digger remained effective against all isolates. Within the field isolation nurseries, the winter barley cultivars displayed a range of quantitative responses to two isolates, with some cultivars expressing high levels of resistance. Cultivars Armelle (BBR1) and Osiris (BBR 6) were resistant, although one isolate tested, race octal 77, carries the corresponding virulence factors. The resistance of the spring barley cultivar Digger remained effective.

Net blotch of barley

Virulence for 11 of 13 differential cultivars was detected in 15 isolates of Pyrenophora teres Drechs. tested on seedlings. Isolates carried between one and seven specific virulences in various combinations. The frequency of virulence for cultivar Marinka was at a reduced level in 1991. In a field isolation nursery, spring barley cultivars displayed a range of quantitative responses to the widely virulent isolate BNS 90-3.

Barley yellow mosaic and barley mild mosaic viruses

Of 203 infected samples received in 1991, 49% contained barley yellow mosaic virus (BaYMV) and 63% barley mild mosaic virus (BaMMV). As in previous years, BaMMV was more frequent on malting cultivars (Maris Otter, Halcyon, Pipkin and Puffin) whereas BaYMV predominated amongst cultivars used for feed. Six new outbreaks of BaYMV were reported from cultivars previously regarded as immune bringing the UK total to 12.

Mildew of oats

Virulence for the resistance derived from Avena barbata (OMV4) was detected at an increased frequency (73%) in 1991. Twenty seven isolates combined this virulence with OMV 1,2,3, making them capable of attacking all currently grown commercial cultivars. Race 5 (OMV 1,2,3) showed a decreased frequency (19%) compared with recent years. One isolate was identified as race 3 (OMV 1,2).

Crown rust of oats

Three virulence combinations were identified in 1991. All had been previously identified in the UK, although only one, race 251, occurs commonly.

Variety Diversification Schemes for 1992

The schemes for mildew of barley and yellow rust of wheat have been updated for 1992. A new scheme for brown rust of wheat has been introduced, which should be of particular benefit to farmers in areas where there is a high risk of brown rust infection. It is recommended that this scheme should be used in conjunction with the yellow rust scheme.

SUMMARY OF SURVEY OF WINTER WHEAT DISEASES IN ENGLAND AND WALES 1991

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From a stratified sample, 382 randomly selected crops of winter wheat were examined for foliar and stem base diseases during the milky-ripe growth stage in July 1991. Septoria tritici was the most widespread and severe foliar disease, occurring in 80% of the crops surveyed and affecting over 4% of the second leaf, with crops in the south-east being the most heavily infected. The disease has only occurred at a higher level in these surveys in 1972, 1981, 1985 and 1987. Mildew was also more important than at any time in the past six years, affecting on average just over 1% of the second leaf. It was most prevalent in the Midlands and West region. The incidence and severity of Septoria nodorum also rose slightly from the very low levels recorded in 1989 and 1990, but was still only recorded in 27% of crops. Both brown rust and yellow rust fell back sharply to pre-1988 levels, with only brown rust in the extreme south-east and parts of the south-west being of any significance. Overall, total foliar disease levels were higher than in any year since 1987, largely due to increased levels of Septoria tritici and mildew.

Eyespot was recorded in a similar number of crops to that found in recent years, but the incidence of stems affected by moderate and severe symptoms showed an increase compared to 1989 and 1990. Sharp eyespot was recorded in just over 60% of crops, but the incidence of moderate and severe symptoms was lower than at any time since 1986. Fusarium symptoms were recorded in 83% of crops, a decrease of some 15% compared to the previous two years. Both nodal and internodal Fusarium symptoms were less severe than in 1990, but there was an increase in the incidence of Fusarium ear blight particularly in the south-east. Plants with visible above-ground symptoms of take-all were present in 26% of the survey fields, with take-all patches being seen in 9% compared to 13% in 1990 and 17% in 1989. There was a large reduction in the number of crops with visible BYDV symptoms, with only 8% of crops affected compared to almost 60% in 1990. The number of fields in which patches of the disease were seen was 2.4% of the total compared to 23% in 1990.

Riband was the most popular variety accounting for 29% of the survey samples. Mercia's share of the samples fell from 26% in 1990 to 17%, while that of Apollo remained unchanged at 12%. The highest level of mildew and the lowest level of Septoria tritici were both recorded on Apollo. Riband carried the highest level of Septoria tritici. Variations in agronomic factors such as previous cropping and sowing date also affected disease levels. Fungicide sprays were used on 93% of crops, the most popular regime being a first spray at growth stage 31 followed by a second spray at or after growth stage 59. 17.5% of crops were grown from seed treated with a non-mercurial fungicidal seed dressing.

SUMMARY OF WINTER BARLEY DISEASES IN ENGLAND AND WALES 1991

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From a stratified sample, 352 randomly selected crops of winter barley were examined for foliar and stem base diseases during the watery-ripe to early-milk stage in June 1991. Mildew was the most widespread and severe foliar disease, occurring in over 90% of the samples and reaching a higher level than in either 1989 or 1990. It was most prevalent in the Midlands and West region. In contrast, brown rust was recorded in only 67% of samples compared to over 90% in each of the previous two years and was less severe than for the past three years. Although rather more prevalent than in 1990, *Rhynchosporium* again occurred at a relatively low level, with only Wales and the extreme south-west recording more than 1% on the second leaf. Net blotch showed some recovery compared to the exceptionally low levels recorded in the previous year but remained much less important than in 1987 and 1988. It reached its highest levels in the south-west and east. Overall, total foliar disease severity was similar to that recorded in 1990 mainly due to the large reduction in brown rust levels which offset the increases in mildew, *Rhynchosporium* and net blotch.

The reduction in eyespot severity seen over the past two years was reversed with levels of moderate eyespot symptoms increasing compared to 1990, but this disease also failed to re-gain pre-1989 levels. The incidence and severity of sharp eyespot was lower than that recorded in any previous winter barley survey. Symptoms associated with *Fusarium* were seen in over 90% of samples and the incidence of moderate nodal and internodal *Fusarium* increased compared to 1990. However, the incidence of severe symptoms was again very low. There was a large reduction in the number of crops with visible BYDV symptoms with only 8% of crops affected compared to 49% in 1990. The number of fields in which patches of the disease were seen was just over 3% of the total compared to 25% in 1990.

Marinka was the most popular variety for the second consecutive year, accounting for 27% of the survey samples received. The highest level of mildew was recorded on Magie. Agronomic factors such as sowing date and previous crop were associated with different disease levels. Fungicide sprays were used on 96% of crops, the most popular regime being a single spray at growth stage 31. 48% of crops received a single fungicide spray application, 38% were sprayed twice and 9% received three or more sprays. 22% of crops were grown from seed treated with a non-mercurial fungicidal seed dressing, a figure similar to that recorded in the previous year. 5% of crops were grown from untreated seed.

MILDEW OF WHEAT

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Virulence factors corresponding to the resistance genes used most widely in winter wheat cultivars in Britain were recorded at high frequencies. Most isolates of mildew carried a combination of virulence factors enabling them to infect most of the cultivars on the NIAB and SAC recommended lists.

INTRODUCTION

The virulence factors corresponding to the resistance genes most widely used in wheat cultivars in Britain have been recorded at high frequencies in the wheat mildew surveys in 1988, 1989 and 1990 (Slater *et al.* 1989, Brown *et al.* 1990, Mitchell & Slater 1991). These resistance genes do not therefore provide effective resistance to mildew in Britain. The survey in 1991 monitored the frequencies of virulences and combinations of virulences matching the main resistance genes, and the frequencies of virulences matching other unidentified resistances.

METHODS

Single colony isolates were derived from samples of infected leaves, and from colonies formed by airborne spores on seedlings of Cerco. This cultivar does not possess any of the resistance factors used in commercial wheat cultivars in the UK, and will be susceptible to all isolates of wheat mildew.

Isolates from infected leaves were mostly from variety trials plots at 10 sites:

NIAB, Cambridge	128 isolates
Hatfield, Hertfordshire	6 isolates
Morley, Norfolk	66 isolates
Lincolnshire	3 isolates
Headley Hall, Yorkshire	40 isolates
Cockle Park, Northumberland	18 isolates
Rosemaund, Hereford and Worcester	1 isolate
Aberystwyth, Dyfed	15 isolates
Powys	2 isolates
Unknown	4 isolates

The source cultivars were:

Winter cultivars

Hereward, Pastiche (WMR 0)
Galahad, Axial (WMR 2)
Beaver, Haven, Admiral (WMR 7)
Talon (WMR 2,6)
Hornet, Tara (WMR 2,7)
Torfrida, Rendezvous (WMR 2,4,6)

Apollo, Hussar (WMR 2,4,7)
Riband (WMR 2,4,8)
Estica (WMR 6,8)
Mercia (WMR 8,m), Urban (WMR 8, m?)
Camp Remy, Soisson (unknown specific resistance)

Spring cultivars
Alexandria, Isis (WMR 0)
Tonic (WMR p)
Baldus (WMR r?)
Troy (WMR 4, r?)
Canon (WMR 6, r?)
Axona (WMR Ax)
Yuri (unknown specific resistance)

In addition, 20 isolates from 5 samples from triticale were tested.

Single colony isolates were taken at random from seedlings of Cerco exposed to infection by airborne spores in March, June and October at NIAB, Cambridge, and in June from SCRI, Dundee.

All isolates were tested for virulence on detached leaves of the differential cultivars listed in Table 1. Heun & Fischbeck (1987) have identified Apollo as carrying resistance factors WMR 2,4,7 (*Pm2, Pm4b, Pm8*), and have suggested that WMR 5 (*Pm5*) and WMR 8 (*Mli*) are identical. 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 mildew in 1991.*

WMR group	Resistance genes	Cultivar
0	None	Cerco
2	*Pm2*	Galahad
4b	*Pm4b*	Armada
2,6	*Pm2, Pm6*	Brimstone
7	*Pm8*	Clement
2,7	*Pm2, Pm8*	Hornet
8	*Mli*	Flanders
8,m	*Mli*, ?	Mercia
2, 'Talent'	*Pm2*, ?	Brock
2,7,x	*Pm2, Pm8*, ?	Slejpner
2,4,7	*Pm2, Pm4b, Pm8*	Apollo
8,p	*Mli*, ?	Tonic
8,r	*Mli*, ?	Sicco
'Axona'	?	Axona
9	*Mld*	Maris Dove *
q	?	Broom *
'Sona'	?	Wembley *

* Not all isolates were tested against Maris Dove, Broom and Wembley

RESULTS

Virulence Frequencies
The frequencies of WMV 2, 4, 6, 7, 8, 8+m, 9 and 'Axona' are given in Table 2.

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

	Frequency of virulence factors (%)				
		Random samples of airborne spores			
Virulence		NIAB, Cambridge			SCRI,
factor	Leaf sample	March	June	October	Dundee
2	100	99	98	100	100
4	69	72	72	68	78
6	80	72	72	78	89
7	80	83	82	84	89
8	92	93	93	86	89
9	Not tested	9	Not tested		Not tested
8,m	50	51	37	19	11
'Axona'	10	3	5	0	0
No. of isolates	300	100	83	37	9

All virulence factors were recorded at high frequency, with the exceptions of WMV 9 and WMV 'Axona'. WMR 9 is not at present used in commercial wheat cultivars in the UK, but the presence of the corresponding virulence at 9% in the March sample of airborne spores suggests that it would not give effective resistance against mildew.

The only cultivar on the NIAB or SAC recommended lists with WMR 'Axona' is Axona itself. As a spring wheat, Axona makes up only a small part of the national wheat acreage, and its influence on the wheat mildew population will be small.

Uncharacterized Resistance Factors
Virulence for the additional resistance factor carried by Slejpner (WMR 2,7,x) was recorded at high frequencies, as in previous years.

Tests on Isolates from Triticale
All 20 of the isolates from infected leaves of triticale were virulent on Cerco, and their virulence factors suggested that they were typical of wheat mildew. When tested on detached leaves of 5 triticale cultivars, only one of the isolates was virulent on one of the cultivars. In all other cases, the mildew isolates were avirulent on triticale.

Complexity of Isolates
Nearly all isolates carried 4 or more of virulence factors WMV 2, 4, 6, 7 and 8, and also carried one or more of the uncharacterized resistance factors. Most isolates would be able to infect several of the most widely grown winter wheat cultivars. The frequencies of the most common pathotypes defined by WMV 2,4,6,7 and 8 are given in Table 3.

The frequency of pathotype WMV 2,4,6,7,8 was very high compared to 1990. This pathotype will be able to infect Beaver, Haven, Apollo, Riband, Hornet, and several other varieties which together made up a large proportion of the national wheat acreage in 1991.

Table 3. *Frequencies of the most common wheat mildew pathotypes, defined by WMV 2, 4, 6, 7 and 8.*

	Frequency of pathotypes (%)				
		Random samples of airborne spores			
		NIAB, Cambridge			SCRI,
Pathotype	Leaf sample	March	June	October	Dundee
2,4,6,7	4	3	5	3	0
2,4,6,8	5	2	0	0	11
2,4,6,7,8	55	57	61	59	67
2,4,7,8	6	7	10	5	0
2,6,7,8	10	5	10	5	0
2,6,8	5	0	5	0	0
2,7,8	6	7	2	5	11
Total no. of pathotypes	17	13	12	9	4
No. of isolates	317	100	83	37	9

Resistance Factors in New Cultivars

The resistance factors in winter and spring wheat cultivars currently recommended by NIAB and the SAC are given in Table 4. Apollo has been classified as WMR 2,4,7 (Heun & Fischbeck 1987). The reactions of all isolates tested in 1991 were consistent with this classification.

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

WMR 0		**WMR 7**		**WMR 2,7**	
Hereward	(W)	Admiral	(W)	Hornet	(W)
Pastiche	(W)	Beaver	(W)		
Alexandria	(S)	Haven	(W)	**WMR 8**	
		Hussar (+?)	(W)	Mercia (+m)	(W)
WMR 2				Tonic (+p)	
Avalon	(W)	**WMR 2,4,7**			
Galahad	(W)	Apollo	(W)	**WMR 'Axona'**	
Norman	(W)			Axona	(S)
Talon (+?)	(W)	**WMR 2,4,8**			
		Riband	(W)	**Unknown**	
				Baldus	(S)
				Canon	(S)

(W) winter wheat, (S) spring wheat

CONCLUSIONS

1. Virulence factors corresponding to the resistances used most widely in winter wheat cultivars in Britain were recorded at high frequencies. The resistances are no longer effective in controlling mildew. However, most currently recommended winter wheat cultivars have good background resistance.

2. Most isolates of mildew carry a combination of virulence factors enabling them to infect most of the cultivars on the NIAB and SAC recommended lists. A diversification scheme to reduce the spread of mildew between crops is therefore of little value.

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YELLOW RUST OF WHEAT

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The frequencies of virulences WYV 1, WYV 2, WYV 3, WYV 4, WYV 6 and WYV 9, remained high. Virulence for Talon increased to 41% in 1991 from 1% in 1990. Virulence was detected for the first time for Hereward, Estica and Hussar.

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	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, Kavkaz 4XFederation	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 1991				
WYR ?7,9	-	-	Tara	
WYR Rx	-	-	Talon	
WYR Rx	-	-	Hereward	
WYR R	-	-	Estica	
WYR R	-	-	Hussar	

* O = Overall A = Adult Plant

** Differential cultivars used in 1991 seedling tests are underlined

METHODS

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

1991 isolates

There was a relatively low incidence of yellow rust in 1991. 42 isolates were tested for virulence in seedling tests, using the differential cultivars indicated in Table 1. Isolates came almost entirely from eastern areas of the UK (East Anglia (18), North East England and Scotland (14), Lincolnshire (8)) and had been collected from 19 cultivars (Talon (5), Beaver (4), Admiral, Axial, Haven, Hereward, Hornet, Riband and Slejpner (3 each), others (12)).

1990 isolates

15 isolates (Table 2) were tested on adult plants of 27 cultivars in Polythene tunnels and on seedlings of the same cultivars in controlled environment chambers. The isolates comprised two control isolates brought forward from 1989, nine new isolates from the 1990 survey and four isolates from 1990 inoculated tests.

Table 2. Isolates of *Puccinia striiformis* used in adult plant tests

Isolate Code	Source		WYV Factors
	Cultivar	Location	
88/149	Fortress	Northumberland	1,2,3,4,6,9,13,14
89/213	Beaver	Northumberland	1,2,3,4,6,9,13,14
90/36	Alexandria	Kent	1,2,3,4,6,7,9
90/41	Brock	Lincs	2,3,4,7
90/43	Haven	Lincs	1,2,3,4,6,7,9
90/51	Haven	Lincs	2,3,4,6,9
90/61	Axial	Lincs	1,2,3,4,9
90/69	Hereward	Essex	1,2,3,4,6,9
90/73	Apollo	Essex	1,2,3,4,6,7,9
90/80	Talon	Lincs	1,2,3
90/85	Haven	Scotland	1,2,3,4,6,9
90/503	Tara	inoculated 89/A2	1,2,3,6,7,9
90/505	Brock	inoculated 89/205	1,2,3,4,7
90/514	Pastiche	inoculated 89/162	1,2,3,4,6,9
90/517	Pastiche	inoculated 89/205	1,2,3,4,6,7,9

RESULTS

1991 Survey isolates

Virulence frequencies are given in Table 3.

Table 3. Virulence factor frequency (%)

WYV Factor	1978	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91
WYV 1	73	83	95	71	63	85	75	76	78	87	68	62	85	91
WYV 2	97	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 3	100	100	85	95	100	100	100	100	100	100	100	100	100	100
WYV 4	27	17	15	29	37	20	31	45	70	47	78	97	91	86
WYV 5	0	0	0	0	0	0	0	*	*	*	*	*	*	*
WYV 6	26	17	25	31	29	26	64	90	96	89	72	57	69	64
WYV 7	0	0	0	5	5	0	3	3	22	8	6	2	9	19
WYV 8	0	0	0	0	2	0	0	*	*	*	*	*	*	0
WYV 9	0	0	0	5	2	23	31	3	4	5	66	99	94	88
WYV 10	0	0	0	0	0	0	0	*	*	*	*	*	*	*
No. of isolates	66	30	20	42	41	63	36	29	23	52	71	156	67	42
Virulence for additional test cvs														
Tara WYR ?7,9													18	21
Talon WYR Rx														41
Hereward WYR Rx														36
Estica WYR R														24
Hussar WYR R														12

* differential not included in test

The frequencies of virulences WYV 1, WYV 2, WYV 3, WYV 4, WYV 6 and WYV 9 remained high and there was a slight increase in the frequency of WYV 7. The differential cultivar Compair (WYR 8) was reintroduced after a break of six years, but no corresponding virulence was detected.

The frequency of virulence for the cultivar Talon, first detected in a single sample in 1990, increased sharply to 41%. Virulence was detected for the first time for three other commercial cultivars - Hereward, Estica and Hussar. There are indications from elsewhere that the resistances of Talon and Hereward are related to that of the European yellow rust differential cultivar Carstens V, although Talon and Hereward appear to have additional components of resistance, which differ from each other. Estica may also fall into this category.

Amongst the 1991 isolates, virulence:avirulence for Hereward, Talon and Estica were positively associated (Table 4), giving a further indication that the resistances of these cultivars have a common element.

Table 4. 2x2 contingency tables for numbers of isolates of <u>Puccinia striiformis</u> virulent:avirulent on cultivars Talon, Hereward and Estica, 1991

		Hereward V	Hereward A			Estica V	Estica A			Estica V	Estica A
Talon	V	13	4	Talon	V	10	7	Hereward	V	9	6
Talon	A	5	20	Talon	A	0	25	Hereward	A	1	26

V = virulent A = avirulent

Talon : Hereward, X^2 = 13.177, P=0.001
Talon : Estica, X^2 = 19.301, P=0.001
Hereward:Estica, X^2 = 16.847, P=0.001

The most frequent pathotype, as in 1990, was WYV 1,2,3,4,6,9, possessing six specific virulence factors (Table 5). 10% of isolates possessed seven virulence factors (WYV 1,2,3,4,6,7,9), whilst none possessed fewer than four.

Table 5. Pathotypes of <u>Puccininia</u> <u>striiformis</u> detected in 1991

Pathotype	Frequency (%)
WYV 1,2,3,4,6,9	50
WYV 1,2,3,9	12
WYV 1,2,3,4,9	12
WYV 1,2,3,4,6,7,9	10
WYV 2,3,4,7,9	5
WYV 1,2,3,4,7,9	5
Other	7

Adult plant tests

The results of adult plant tests in Polythene tunnels are given in Table 6. The virulence factors attributed to each isolate have been deduced from seedling tests and 1991 adult plant tests.

The cultivars Parade, Rendezvous, Torfrida, Pastiche, Mercia and Estica maintained their high levels of resistance to all isolates, with the new cultivar Hussar displaying similar resistance.

The resistance of Talon and of Axial was overcome by two new isolates, 90/80, collected from Talon, and 90/61, collected from Axial. The second of these also gave low levels of infection on Hereward, which had previously been resistant to all isolates. Seedling tests showed that both isolates possess virulence for Carstens V, lending weight to suggestions that the resistance of Talon, Axial and Hereward is derived partly from this cultivar. Trace levels of infection were also recorded on Estica with these isolates, which is consistent with other indications that Estica's resistance may be related to this group.

The specific resistance of Admiral, was identified as WYR 9. The cultivar has a moderate level of adult plant resistance similar to that of the WYR 9 cultivar Apollo. Although there was some variation in infection levels on Admiral between different WYV 9 isolates, this could not be related to other identified virulence characters.

Infection on Tara inoculated with isolate 90/503 was noticeably higher than with other isolates tested in 1991 or 1990. 90/503 possesses the relatively uncommon combination of WYV 7 with WYV 9, but appears to lack virulence for the adult plant resistances WYR 13 or WYR 14, either of which might be required to match adult plant components of Tara's resistance. However, 90/43, which appears to possess WYV 7,9 together with both WYV 13 and WYV 14, was somewhat less virulent on Tara than 90/503. Despite concern over the cultivar's vulnerability to yellow rust, due to its highly susceptible parentage (Brock, WYR 7, x Clement, WYR 9), it has so far maintained a high level of resistance.

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Table 6. Adult Plant Tests 1991. Values are per cent leaf area infection (mean of 5 assessments)

Cultivar	Isolate	90/41	90/505	90/517*	90/43	90/503	90/80	90/61	88/149	89/213	90/69	90/85	90/514	90/36	90/73	90/51
	WYV factors	2,3,4,7,14	1,2,3,4,7,14	1,2,3,4,6,7,9,13,14	1,2,3,4,6,7,9,13,14	1,2,3,4,6,7,9	1,2,3	1,2,3,4,9,13,14	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	1,2,3,4,6,(7),9,13,14	2,3,4,6,9,14
	WYR factors															
Parade	R	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	0	0
Torfrida	Rx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hussar	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pastiche	0+APR	1	1	1	0	1	1	1	1	0	0	1	0	0	0	0
Mercia	3+APR	0	0	0	1	0	1	1	1	0	1	0	0	0	2	0
Estica	R	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0
Hereward	Rx	0	0	0	0	0	0	4	0	0	0	0	1	0	0	0
Talon	Rx	2	0	0	0	0	16	6	2	0	0	1	3	1	2	2
Axial	Rx	1	1	2	4	1	12	18	1	1	5	6	9	0	4	1
Avalon	4,14	8	4	4	7	2	1	2	7	2	7	3	5	2	1	4
Galahad	1,2,14	0	4	4	7	1	1	3	6	6	7	3	4	1	7	0
Kinsman	6,13	2	2	8	4	5	4	5	10	9	11	7	4	7	3	6
Longbow	1,2,6,13	4	1	9	3	2	1	3	8	4	11	11	4	3	5	4
M.Huntsman	2,13	2	3	6	5	3	3	3	6	6	10	6	8	4	7	1
Hustler	1,2,13	1	2	9	8	4	3	14	12	11	12	9	7	9	9	6
Riband	13	3	2	6	4	3	3	9	8	9	7	9	5	2	6	1
Hobbit	14	9	7	7	10	1	2	10	11	8	12	10	10	12	16	8
Clement	9	14	22	17	23	18	10**	26	18	23	18	21	26	27	17	9
Apollo	9	2	2	1	5	3	2	16	6	3	5	10	1	2	5	1
Admiral	9	1	0	0	8	2	2	5	10	11	9	10	8	1	9	2
Hornet	6,9	7	4	1	21	24	11**	13**	19	20	16	18	17	12	20	13
Haven	6,9	2	2	1	11	16	10**	9**	12	13	11	12	10	6	10	13
Beaver	6,9	1	1	0	8	2	2	7**	9	7	10	10	8	1	10	7
Brock	7,14	12	8	7	14	2	0	0	0	0	0	3	0	0	0	2
Tommy	7	20	12	8	12	14	8	1	2	3	0	1	1	5	1	3
Tara	?7,9	0	0	0	2	4	1	0	0	0	0	0	0	1	0	2

() virulence identified in seedling tests in 1990, but not confirmed in 1991
* apparent loss of WYV 9 after initial seedling test
** evidence of contamination with WYV 6,9 during adult plant test

BROWN RUST OF WHEAT

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Glasshouse seedling tests with the 1991 isolates of P. recondita identified the winter wheat cv. Zodiac as carrying the resistance factor WBR-1. The spring wheat cv. Baldus gave a similiar pattern of response to cv. Sappo (WBR-3) to the isolates in seedling and adult plant field tests. Virulence to cv. Slejpner (WBR-1 + adult plant resistance) was identified in a field nursery inoculated with isolate WBR-90-9 (WBV-1,2,6). The 'breakdown' of this resistance was confirmed in glasshouse tests where other cultivars carrying the same resistance were susceptible to the same isolate. The resistance of the winter wheat cvs Pastiche, Hereward, Torfrida, Hussar and Estica was effective against the field isolates as was that of the spring cvs Axona and Troy.

GLASSHOUSE SEEDLING TESTS WITH 1991 ISOLATES

Sixty three samples of *Puccinia recondita* were received from winter (61) and spring (2) wheat cultivars in 1991. This number included forty-two sent from the ADAS Cereal Disease Survey. The 61 samples received from England were from 4 different ADAS regions (Table 1), and 2 samples came from Wales. In addition, 3 isolates of leaf rust collected from *Triticale* (cv. Lasko) and 1 sample from rye were received from Dr. Henriette Goyeau, Grignon, France.

Table 1. Geographical location of 1991 wheat brown rust samples

ENGLAND (ADAS region)	Number of samples
East	12
West central	15
East central	26
South west	8

Isolates were obtained from 51 of the UK samples of which 18 have been successfully tested on differential cultivars which comprised the standard WBR reference cultivars, 9 spring and winter wheat cultivars from the NIAB Recommended List and Recommended List trials, and 5 Triticale cultivars (Table 2). Two isolates were cultured from the French Triticale samples one of which was successfully tested on the complete set of tester cultivars.

Table 2. Differential cultivars

Standard differential cultivars		Spring* and winter cultivars	Triticale
Clement	(WBR-1)	Troy*	Pablo
Maris Fundin	(WBR-2)	Baldus*	Lasko
Norman	(WBR-2)	Hussar	Purdy
Hobbit	(WBR-2)	Hunter	Alamo
Sappo	(WBR-3)	Brigadier	Cumulus
Maris Halberd	(WBR-4)	Spark	
Gamin	(WBR-6)	Zodiac	
Sterna	(WBR-7)	Genesis	
Sabre	(WBR-7)	Cadenza	
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 1991 pathogen isolates

Cultivar	WBR factor	Virulence combination				Virulence frequency
Clement	1	S	S	S	R	0.94
Fundin	2*	S	S	S	S	1.00
Norman	2*	S	S	S	S	1.00
Hobbit	2*	S	S	S	S	1.00
Sappo	3*	R	R	S	R	0.06
Halberd	4*	R	S	S	R	0.11
Gamin	6	S	S	S	S	1.00
Sterna	7*	R	R	R	R	0
Sabre	7*	R	R	R	R	0
Armada	0	S	S	S	S	1.00
No. of isolates		15	1	1	1	

* Temperature sensitive

Seventeen of the isolates were virulent on cv. Clement (WBR-1). The winter wheat cv. Zodiac gave a similiar pattern of response although it displayed a mixed mainly susceptible response to some of the isolates at 25°C. The temperature sensitive resistance WBR-2, present in cvs Maris Fundin, Hobbit and Norman was overcome by all isolates, confirming the high frequency of virulence to this resistance in recent years. One isolate, WBRS-91-2 was virulent on cv. Halberd (WBR-4) at both temperature regimes but was avirulent on cv. Sappo at 10°C. Isolates differentiating these resistances have been identified previously but are not common. The remaining isolates were all virulent on both cultivars at 25°C and avirulent at 10°C with the exception of isolate WBRS-91-54 which was compatible at both temperature regimes. The response of the spring wheat cv. Baldus to the isolates suggests that it carries WBR-3. Cv. Gamin (WBR-6) was susceptible to all the isolates.

All the 1991 isolates were avirulent on cvs Sterna (WBR-7) and Sabre (WBR-7) at 25°C, but gave a more susceptible reaction at the lower temperature regime, three of the isolates being fully compatible with both cultivars at 10°C. Isolate WBRS-91-61 sampled from the Triticale cv. Lasko in France carries WBV-6 only, although a mixed susceptible reaction was observed at 10°C on cultivars carrying WBR-2. It was virulent on cvs Sappo (WBR-3) and Halberd (WBR-4) at the high temperature regime. Of the five Triticale cultivars included in the tests cv. Lasko only was susceptible to this isolate.

The spring wheat cv. Troy and the winter cvs Spark and Genesis were susceptible to all the isolates. The winter wheat cvs Hussar, Hunter, Brigadier and Cadenza gave mixed patterns of response to the isolates. Within the Triticale cultivars Alamo was resistant at both temperature regimes, whilst only two isolates induced a susceptible reaction, of a mixed type, on cv. Purdy, this being at 10°C.

Cultivars Pablo and Cumulus displayed a mixed resistant response to the majority of the isolates. Virulence to cv. Lasko was carried by 70% of the isolates.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Two isolates were tested on adult plants in field isolation nurseries in 1991. The isolates used were :

Isolate		Origin
WBRS-90-9	(WBV-1,2,6)	cv. Avalon, Wykeham, Spalding, Lincs
WBRS-90-37	(WBV-2,6)	cv. Mercia, Wye, Kent

The virulence factors carried by the two isolates were identified from seedling tests and it may be that the isolates carry additional virulence(s) which can only be identified at the adult plant stage of growth. Each nursery comprised 29 winter and 9 spring wheat cultivars. Assessments of percentage infection and reaction type were made throughout the season.

Results

These are summarised in Table 4. High levels of disease built up on the susceptible winter cultivars in both nurseries. Disease was slower to increase on the spring cultivars although by the end of the season reasonable levels were achieved. Using data from the field nurseries, together with that from seedling test results and previous years' results, some of the wheats were placed into resistance groups. Several of the cultivars showed a pattern of response to the two isolates similar to cv. Clement (WBR-1). These included Hornet, Beaver, Haven and Apollo, confirming 1990 field tests. Previous results had indicated that cvs Beaver and Hornet carried additional adult plant resistance (Jones & Clifford, 1990). Cv. Slejpner has been identified in seedling tests as carrying WBR-1 (Jones & Clifford, 1986) it also carries additional adult plant resistance and has been effective against all WBV-1 isolates tested in field nurseries in recent years. Field nursery tests in 1991 suggest that this resistance may be breaking down as isolate WBRS-90-9 (WBV-1,2,6) produced '4-type' pustules on cv. Slejpner although the infection was of a mainly resistant type. Cv. Tara, which responded similarly to cv. Slejpner to the 2 field isolates in 1990 adult plant tests, was highly susceptible to isolate WBRS-90-9. Virulence to cvs Slejpner, Tara, Beaver and Hornet was confirmed in glasshouse adult plant tests when they were tested against an isolate cultured from infected leaves of cv. Slejpner sampled from the isolation nursery inoculated with isolate WBRS-90-9. Low levels of rust were recorded on WBR-1 cultivars within the nursery inoculated with isolate WBRS-90-37 (WBV-2,6) which does not carry the corresponding virulence. This was probably due to contamination of the nursery with WBV-1 pathotypes.

Cvs Fundin, Norman, and Hobbit (WBR-2) were less heavily infected within the nursery inoculated with isolate WBRS-90-9 although both isolates carry the corresponding virulence WBV-2. Cvs Hobbit and Norman, which carry additional resistance to Fundin (Clifford et al., 1982), were less susceptible, particularly in the case of cv. Norman.

Seedling tests with 1991 isolates suggest that the spring wheat cv. Baldus carries WBR-3. This was confirmed in the isolation nurseries where it gave a similar response to cv. Sappo (WBR-3).

Cv. Gamin (WBR-6) was more susceptible to isolate WBRS-90-37 (WBV-2,6) despite both isolates being identified in seedling tests as carrying the corresponding virulence WBV-6. This pattern of response has been observed previously. (Jones & Clifford, 1989).

Both isolates were virulent on cv. Avalon which carries the adult plant resistance factor WBR-9. The resistance of the winter wheat cvs Pastiche, Hereward, Torfrida, Hussar and Estica was effective against both isolates as was that of the spring cvs Axona and Troy. These results, together with seedling tests, suggest that their resistance is effective against WBV-factors 1,2,3,4,5,6 and 9.

The winter cvs Mercia, Galahad, Riband and Axial are grouped together. All displayed a mixed susceptible response at fairly low infection levels to isolate WBRS-90-9, but higher levels of disease of a mainly resistant type were observed within the nursery inoculated with isolate WBRS-90-37. The remaining cultivars were susceptible to varying degrees to both isolates. The cultivar rankings between isolates follow a similar pattern.

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Table 4. Reactions+ of winter and spring* wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1991

Cultivar	(NIAB rating)	WBR factor	Isolates WBRS-90-9 (WBV-1,2,6)		WBRS-90-37 (WBV-2,6)	
Clement		1	17	S	2	S
Beaver	(4)		21	S	2	S
Haven	(3)		22	S	5	S
Tara			17	S	0.2	S
Hornet	(6)		14	MS	6	S
Apollo	(6)		15	MS	3	S
Slejpner	(8)		7	MR	Trace	S
Admiral	(6)		9	MS	2	S
Fundin		2	6	S	26	S
Hobbit			6	S	14	MS
Norman			3	MS	8	MR
Sappo*		3	0.5	S	0.3	S
Canon*			0		0	
Baldus*	(8)		Trace	S	Trace	S
Halberd*		4	0.1	S	0	
Huntsman		5	7	MS	12	MS
Gamin		6	2	S	16	S
Sabre		7	0		0	
Sterna			0.1	S	Trace	S
Ranger		8	0.5	S	0.5	S
Kinsman		8?	Trace	S	Trace	MR
Avalon	(5)	9	22	S	21	S
Torfrida			0		0	
Hussar	(9)		0		0	
Troy*			0		0	
Axona*	(8)		0		0	
Estica			Trace	S	0	
Hereward	(8)		Trace	S	0.5	MS
Pastiche	(8)		0.2	S	0	
Mercia	(5)		3	MS	13	MR
Galahad	(4)		4	MS	14	MR
Riband	(4)		7	MS	13	MR
Axial			7	MS	14	MR
Isis*			5	S	8	S
Alexandria*	(4)		6	S	11	S
Tonic*	(3)		12	S	12	S
Armada			17	S	18	S
Talon	(2)		21	S	26	S

\+ Mean of 3 replicates, 3 assessment dates (winter cvs)
Mean of 4 replicates, final assessment date (spring cvs)
S = susceptible, MS = Mixed Susceptible, MR = Mixed Resistant
( ) NIAB rating: 1 = susceptible, 9 = resistant

MILDEW OF BARLEY

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Individual barley mildew virulence factors and combinations of virulence factors matching the specific resistances used in barley cultivars in Britain were mostly recorded at high frequencies in the 1991 survey. The combinations BMV7, BMV6c,7 BMV6c,8 and BMV4,10 were recorded at the lowest frequencies. Virulence for BMR9 (*mlo*) was not detected, and this gene continues to provide effective resistance to mildew. The most common pathotypes carried a large number of virulence factors, and the most complex isolate identified so far carried 12 of the 13 virulence factors tested for in the survey.

INTRODUCTION

The surveys of barley powdery mildew carried out since 1988 (Slater *et al.* 1989, Brown *et al.* 1990, Mitchell & Slater 1991) have shown that the specific 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 the gene *mlo*.

The 1991 survey continued with the aims of:

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

2. Determining the specific resistances in new cultivars.

3. Estimating the frequencies of virulence combinations able to infect more than one diversification group for compilation of the variety diversification scheme.

METHODS

Single colony isolates were derived in two ways; from infected leaves, and from colonies formed by airborne spores on seedlings of Golden Promise. This cultivar does not possess any of the specific resistance factors used in commercial cultivars in the UK and should be susceptible to all isolates of barley mildew.

Isolates from infected leaves were mostly from variety trials plots at 14 sites:

NIAB, Cambridge	184 isolates
Plant Breeding International, Cambridge	14 isolates
Morley, Norfolk	22 isolates
East Wrentham, Norfolk	25 isolates
Kirby, Essex	15 isolates

Manningtree, Essex	15 isolates
Ongar, Essex	13 isolates
Billingshurst, Sussex	3 isolates
Rosemaund, Hereford and Worcester	3 isolates
Rothwell, Lincolnshire	3 isolates
Tarleton, Lancashire	14 isolates
Cockle Park, Northumberland	26 isolates
Trawsgoed, Dyfed	88 isolates
Pembroke, Dyfed	23 isolates

The source cultivars were:

Winter cultivars
- Bambi, Blanche, Bronze, Clarine, Eagle, Fighter, Finesse, Frolic, Gaulois, Gypsy, Halcyon, Karisma, Magie, Maya, Melusine, Panda, Pastoral, Posaune, Shire and Target (BMR 0,1 or 2)
- Kira and Torrent (BMR 3)
- Puffin (BMR 5)
- Marinka (BMR 1b,6b)
- Manitou and Poacher (BMR 8)
- Pipkin (BMR 10)
- Firefly (unknown specific resistance)

Spring cultivars
- Blenheim and Prisma (BMR 5,6c)
- Triumph (BMR 6b,6c)
- Decor (BMR 6c,7)
- Nomad (BMR 6c,8)
- Camargue (BMR 6c,10)
- Chad, Dove and Teal (BMR 7)
- Derkado, Forester and Hart (BMR 9)
- Dallas and Digger (BMR 10)
- Graphic, Nugget and Tyne (BMR 4,10)
- Sewa (*Mla3, Mlg*)
- 14 cultivars of unknown specific resistance

Single colony isolates were taken at random from seedlings of Golden Promise exposed to infection by airborne spores in March, June and October at NIAB, Cambridge, and in June at SCRI, Dundee.

All isolates were tested for virulence on 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.

Table 1. *Differential cultivars used for determining virulence factors in isolates of barley mildew in 1991.*

BMR Group	European code*	Resistance gene	Cultivar
0	0	None	Golden Promise
1b	Ra	*Mlra*	Igri
1a, 1b	Ha, Ra	*Mlh, Mlra*	Astrix
2a	We	*Mlg*	Goldfoil
2a, 2b	We	*Mlg, Ml(CP)*	Zephyr
3	Sp	*Mla6, Mla14*	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	*Mlk, Mla9*	Simon
9	Mlo	*mlo*	Apex
10	Ru	*Mla13*	Digger
4, 10	La, Ru	*Ml(La), Mla13*	Nugget
6c, 7	Ab, Al	*Ml(Ab), Mla1*	Decor

* Jørgensen, 1987

RESULTS

Virulence Frequencies

The frequencies of BMV 1a, 1b, 2a, 2b, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10 in the sample from infected leaves (leaf sample) and in the random samples of airborne spores from NIAB and SCRI are given in Table 2. Frequencies of virulence factors in the leaf sample are presented in two ways; all data, and excluding those virulences in individual isolates which match the resistances in the host cultivar (unnecessary virulence frequencies). Considering the frequencies of virulences only where they are unnecessary for infection of the host cultivar will reduce the effect of host resistance in selecting virulences from the pathogen population.

All of these virulence factors, with the exception of BMV 7, were recorded at 10% or more in each sample. BMV 1a, 1b, 2a, 2b, 5, 6a, 6b and 6c were recorded at high frequencies in all of the samples. Virulence for BMR 9 (*mlo*) was not detected in any isolate, including 9 isolates from cultivars with BMR 9. Differences between the leaf sample and the NIAB random samples of airborne spores were small.

In the leaf sample, the frequencies of BMV 4, 7, 8 and 10 were lower when unnecessary virulences were compared with the whole data set. These virulence factors occurred at lower frequencies in the leaf sample than most other virulence factors.

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

Virulence factor	Frequency of virulence factors (%)					
	Leaf sample		Random samples of airborne spores			
			NIAB, Cambridge			SCRI,
	All data	Unnecessary virulence*	March	June	October	Dundee
1a	78	77	82	82	88	78
1b	100	100	99	100	100	100
2a	99	99	100	100	97	100
2b	97	97	90	100	92	100
3	28	28	26	28	9	10
4	41	35	18	35	10	50
5	65	67	63	84	48	34
6a	79	78	76	88	78	83
6b	79	76	82	90	82	64
6c	68	62	69	77	70	31
7	22	8	7	12	5	2
8	29	20	21	10	23	43
10	34	16	43	4	51	94
Number of isolates	448		103	51	77	101

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

BMV 4, 8 and 10 occurred at higher frequencies, and BMV 3, 5 and 6c at lower frequencies in the SCRI, Dundee sample compared to the other samples. This probably reflects differences in the acreages of cultivars with corresponding resistance factors in Scotland compared with England and Wales.

The frequency of isolates with combinations of virulence factors enabling them to infect cultivars in each diversification group are given in Table 3. Cultivars with BMR 9 and in diversification group 1 are not included in the table and retain a high level of resistance.

The frequencies of isolates with BMV 6c,7 and BMV 6c,8 were relatively low in all samples. The frequency of isolates with BMV 4,10 was fairly low in the leaf sample and the NIAB random samples of airborne spores, but was high in the SCRI sample.

Records from NIAB variety trials in 1991 indicate that there was increased virulence for Decor (BMR 6c,7) and Nomad (BMR 6c,8) at some sites. It is likely that isolates with the corresponding virulence factors will become more frequent in 1992, reducing the resistance of Decor and Nomad.

Table 3. *Frequency of isolates of barley mildew able to infect cultivars in each Diversification Group.*

Diversification Group and BMR factors		Frequency of isolates able to infect each DG (%)		
			Random samples of airborne spores	
		Leaf sample	NIAB (Mar, Jun & Oct)	Dundee
0	(0,1 or 2)	98	100	100
4	(10)	34	37	94
4	(4,10)	12	3	47
5	(1,2,5)	52	50	23
6	(6b,6c)	57	63	28
7	(7)	22	7	2
7	(6c,7)	12	4	1
8	(8)	29	10	8
8	(6c,8)	12	10	8
9	(4,6a,6b)	31	12	28
10	(1,2,3)	20	17	9
11	(5,6c)	54	53	15
12	(6c,10)	19	22	26
No. of isolates		448	231	101

New Virulence Combinations

Specific virulence for the spring barley cultivar Shirley was identified for the first time in two isolates. The isolates are both common pathotypes in terms of the virulence factors tested for in 1991, apart from their virulence on Shirley. It is likely that Shirley possesses a specific resistance factor other than those listed in Table 1, possibly in combination with one or more of the commonly used resistances.

Complexity of Isolates

The number of virulence factors carried by isolates of barley mildew in the leaf sample and the random samples of airborne spores from NIAB and SCRI are given in Table 4. Nearly all isolates carried 5 or more virulence factors, and isolates from the leaf sample carried more virulence factors than isolates from the other samples. One isolate from the winter barley cultivar Bronze (BMR1b) at NIAB, Cambridge carried 12 of the 13 virulence factors tested for, lacking only BMV3.

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

No. of BMV factors	Frequency of isolates with each no. of virulence factors (%)		
		Random samples of airborne spores	
	Leaf sample	NIAB (Mar, Jun & Oct)	Dundee
0	0	0	0
1	<1	0	0
2	0	0	0
3	<1	2	4
4	<1	4	8
5	3	25	16
6	6	39	32
7	17	22	29
8	32	6	10
9	24	2	2
10	11	0	0
11	5	0	0
12	<1	0	0
13	0	0	0
No. of isolates	448	231	101

Frequencies of Pathotypes

The frequencies of the most common pathotypes in the samples are given in Table 5. In each sample a small number of pathotypes made up 30 to 40% of the sample, with a large number of other pathotypes recorded only once or twice. Most the common pathotypes were recorded in all of the samples, although at varying frequencies. All of the common pathotypes carried BMV 1a,1b,2a,2b, and for clarity these virulence factors have been omitted below.

Pathotypes BMV 5,6b,6c and BMV 5,6a,6b,6c were the most frequent pathotypes in the leaf sample and the NIAB random airborne spore samples. The former pathotype was not detected and the latter was recorded at low frequency in the SCRI, Dundee sample. By contrast, pathotypes BMV 6a,6b,6c,10 and BMV 4,6a,6b,8,10 were the most frequent in the SCRI sample, and were recorded at low levels in the other samples. This probably reflects differences in the acreages of cultivars with corresponding resistance factors in Scotland compared with England and Wales.

Pathotypes BMV 5,6b,6c, BMV 5,6a,6b,6c, BMV 5,6a,6b,6c,10, BMV 6a,6b,8,10 and BMV 6a,6b,6c,8,10 were frequent in 1990 (Mitchell & Slater 1991). The last named pathotype was the most common in 1988 and 1989 (Slater *et al.* 1989, Brown *et al.* 1990).

Resistance Factors in New Cultivars

The resistance factors in cultivars currently included in the barley mildew variety diversification scheme are given in Table 6.

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

Pathotype *	Frequency of pathotype (%)				
		Random samples of airborne spores			
		NIAB, Cambridge			SCRI,
	Leaf sample	March	June	October	Dundee
5 6b 6c	5	8	2	5	0
5 6a 6b 6c	7	10	24	17	2
3 5 6b 6c	6	3	2	1	1
6a 6b 10	2	5	0	8	5
6a 6b 6c 10	3	6	0	5	11
5 6a 6b 6c 10	3	6	4	4	2
6a 6b 8 10	3	2	0	3	3
6a 6b 6c 8 10	3	3	0	9	1
4 6a 6b 8 10	1	0	0	0	9
Total no. of pathotypes	146	57	29	40	50
No. of isolates	448	103	51	77	101

* All named pathotypes also carried BMV 1a,1b,2a and 2b

CONCLUSIONS

The results of the 1991 barley mildew survey follow the conclusions of previous surveys:

1. BMR 9 (*mlo*) continues to provide effective resistance.

2. Nearly all combinations of resistance factors other that BMR 9 are matched by sufficiently high frequencies of the corresponding combinations of virulence factors to make them largely ineffective.

3. The barley mildew population continues to increase in complexity in response to new combinations of resistances in commercial cultivars.

Table 6. *Specific mildew resistance factors of cultivars in the Barley Mildew Diversification Scheme.*

BMR 0		**BMR 9**		**BMR 4,10**	
Clarine	(W)	Alexis	(S)	Tyne	(S)
Gaulois	(W)	Atem	(S)	Nugget	(S)
Halcyon	(W)	Chariot	(S)		
Pastoral	(W)	Dandy	(S)		
Posaune	(W)	Derkado	(S)	**BMR 5,6c**	
Target	(W)	Forester ?	(S)	Blenheim	(S)
Golden Promise	(S)	Hart	(S)	Corniche	(S)
				Prisma	(S)
BMR 1b		**BMR 10**			
Bronze	(W)	Pipkin	(W)	**BMR 6b,6c**	
Igri	(W)	Sherpa (+?)	(S)	Triumph	(S)
Plaisant	(W)				
		BMR 1a,2		**BMR 6c,7**	
BMR 2		Panda	(W)	Decor	(S)
Fighter	(W)				
Frolic	(W)	**BMR 1,2,3**		**BMR 6c, 8**	
Gypsy	(W)	Kira	(W)	Nomad	(S)
Magie	(W)	Torrent	(W)		
Melusine	(W)			**BMR 6c,10**	
		BMR 1,2,5		Camargue	(S)
BMR 6b		Puffin	(W)		
Marinka	(W)			**UNKNOWN**	
		BMR2,4		Firefly	(W)
BMR 7		Golf	(S)	Sprite	(W)
Chad	(S)			Shirley	(S)
		BMR 4,6a,6b			
BMR 8		Klaxon	(S)		
Manitou	(W)				

(W) winter barley, (S) spring barley

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MILDEW OF BARLEY IN NORTHERN IRELAND

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

Table 1. Source of mildew isolates tested in 1991

BMR group	Isolate source	No. isolates
0	Shire	1
1b	Bronze	1
2	Magie	2
	Frolic	1
	Fighter	1
8	Manitou	1
8	Poacher	1
9?	Dandy	1
10	Digger	1
4 + 10	Tyne	2
5 + 6c	Blenheim	3
	Prisma	3
6b + 6c	Triumph	2
1 + 2 + 3	Torrent	1
1 + 2 + 5	Puffin	1
?	Belle	2
?	Osprey	2
?	Rita	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 in 1990 to that outlined by Brown *et al* (1989) although, again as in 1990, scores were taken from leaves on intact plants rather than from detached leaves. The percentage of the various virulence groups on all varieties is given in Table 3, which also gives the frequencies for 1990 as well as the pathogencity values (using the previous scoring system) for 1989.

Table 3. Frequencies of virulence alleles from isolates collected from infected leaves in 1991.

Virulence	No.	Virulence frequencies (%) 1991	Virulence frequencies (%) 1990	Pathogenicity values 1989
2	18/28	68	43	65
3	15/28	54	41	35
4	16/28	57	27	53
5	15/28	54	46	77
6a + 6b	16/28	57	48	42
6b + 6c	20/28	71	33	38
7	4/28	14	20	31
8	8/27	30	27	44
3 + 4	11/28	39	67	32
4 + 5	14/28	50	27	32
4 + 6a	13/26	50	50	37
4 + 6a + 6b	11/27	41	59	43
4 + 9	0/28	0	0	5
10	13/28	43	14	

Because of the change over to the new scoring system in the previous year there are some problems with comparisons over seasons. However, there is a reasonable degree of consistency beteen the values for 1991 and 1990, with a few exceptions. Frequencies of the single major genes 2, 3, 4 & 5 were relatively close to one another in 1991, although BMV 3 had been lower than the others in 1990. The frequency of BMV 6b + 6c increased markedly in 1991 and followed a general trend in increase for that group. Although no currently popular cultivar in N. Ireland has that particular resistance combination, 6b and 6c are found separately in cultivars such as Blenheim, Prisma and Escort. The frequency of BMV 7 remained low, mirroring low figures for GB for 1989 & 1990. No pustules developed on BMR 4 + 9, although one viable isolate was obtained fron cv. Dandy (BMR 9?) confirming findings from the previous year. One striking difference with the previous season was the greatly increased figure for BMV 10, perhaps reflecting the popularity of cv. Digger. Currently, however, the most popular cultivars in N. Ireland are Dandy (BMR 9?), Tyne (4 + 10?), Blenheim & Prisma (5 + 6c) and Escort (4 + 6a + b), Escort being the only one found in the previous year's top five.

Although tests on the effectiveness of Baytan seed-treatment were continued in 1990, results were very variable and were not included in that report. However, results in 1991 were more consistent and are compared with values for 1987 - 89 in Fig. 1. Although there may be some doubt as to the significance of the apparent increase in mildew with the lowest rate of Baytan, the general trend is towards a measure of resistance with time.

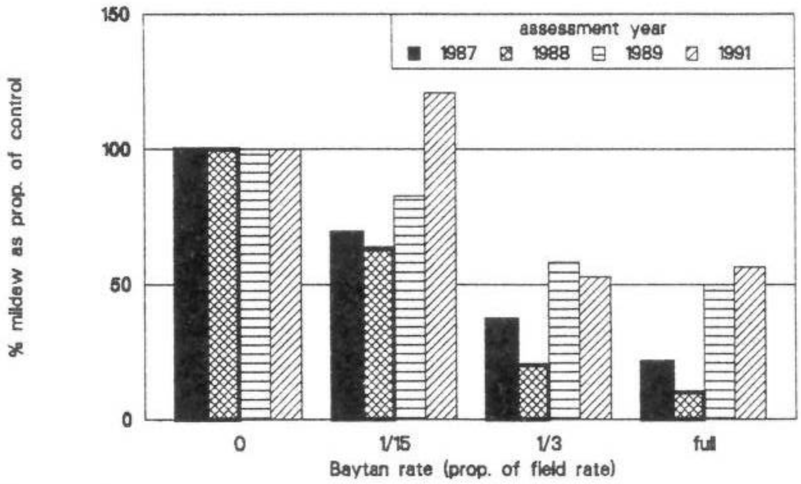

Fig. 1 Percentage of colonies of mildew growing on Baytan-treated seedlings as a proportion of those on untreated seedlings

REFERENCE

Brown, J.K.M, Slater, S.E., Howe, P.M. and See, K.A. (1989). Mildew of Barley. United Kingdom Cereal Pathogen Virulence Survey Annual Report 24 - 31.

YELLOW RUST OF BARLEY

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One isolate possessing BYV 1,2 was received during 1991

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 1991 isolate

One sample was received from Northumberland from the winter cultivar Pipkin.

RESULTS

Virulence frequencies for 1977-1991 are shown in Table 2.

Table 2 Virulence factor frequency (%)

	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91
BYV 1	100	98	100	100	100	100	100	100	-	-	100	-	100	100	100
BYV 2	18	32	0	54	81	96	87	100	-	-	100	-	100	0	100
BYV 3≠	-	-	-	-	-	-	17	86	-	-	22	-	75	0	0
Number of isolates	27	44	1	56	52	25	30	7	0	0	9	0	4	1	1

≠ Not included in tests before 1983.

The 1991 isolate was virulent on the BYV1 differentials Astrix and Atem, and the BYV2 differentials Bigo and Varunda.

REFERENCE

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

BROWN RUST OF BARLEY

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Five previously identified virulence combinations were detected from the 1991 isolates tested. Virulence to cv. Triumph showed an increased frequency (0.93), reversing the trend observed in 1989 and 1990. Two isolates were identified as being the widely virulent race octal 1677, last detected in 1986. Field isolation nurseries showed that the winter barley cultivars display a range of quantitative responses to the 2 introduced isolates. The spring barley cultivars were grouped on the basis of their responses to the three isolates.

GLASSHOUSE SEEDLING TESTS WITH 1991 ISOLATES

One hundred and eighty-one samples of barley brown rust were received from a range of winter barley cultivars, with only 5 samples coming from spring barleys. The total number included 93 samples sent from the ADAS Cereal Disease Survey kindly arranged by Dr. R. Polley. The samples received were from 5 ADAS regions of England and Wales (Table 1).

Table 1. Geographical location of 1991 barley brown rust samples

Location	Number of samples
ENGLAND (ADAS region)	
East	7
West central	25
East central	55
South west	34
South	3
WALES	56
Unknown	1

The large number of samples received prevented the culture and testing of each one, 53 isolates of *Puccinia hordei* having been tested on the standard set of 10 differential cultivers (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	Pa2	2
Ribari	3	Pa3	3
Gold	4	Pa4	4
Quinn	5	Pa5	5
Bolivia	6	Pa6	6
Cebada Capa	7	Pa7	7
Egypt 4	8	Pa8	8
C.I. 1243	9	Pa9	9
Triumph	10	Pa10	10

Results

The virulences combinations identified and their frequencies compared with the previous four years are given in Table 3.

Table 3. Races and their frequencies identified from the 1991 isolates compared with the previous four years

Octal designation	BRV factors	Frequency 1987	1988	1989	1990	1991
1673	1,2,4,5,6,8,9,10	0.54	0.27	0.47	0.49	0.80
1653	1,2,4,6,8,9,10	0.30	0.57	0.18	0.12	0.07
673	1,2,4,5,6,8,9	0.12	0.16	0.35	0.39	0.07
1657	1,2,3,4,6,8,9,10	0.04	0	0	0	0.02
1677	1,2,3,4,5,6,8,9,10	0	0	0	0	0.04
Number of isolates		46	60	73	49	53

Virulence to the differential cv. Ribari (BBR-3) was detected in 3 isolates. The three isolates, cultured from leaf samples of the winter barley cvs Pastoral (2) and Marinka (1) combined this virulence (BBR-3) with the Triumph virulence (BBR-10). Two of the isolates, identified as race octal 1677 combine all the known virulences in the UK population, failing only to overcome the resistance of the differential cv. Cebada Capa (Pa 7). This virulence combination was previously detected in 1986. The frequency of virulence to the differential cv. Triumph (BBR-10) was at an increased level in 1991 (0.93), reversing the trend of recent years (Table 4). The high frequency level of this virulence (BRV-10) is not unexpected as isolates carrying it appear to infect the majority of currently grown winter barleys more readily. The lower values of 1989 and 1990 are difficult to explain as the vast majority of rust samples were also from winter barley cultivars.

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
1991	0.93	53

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Two nurseries comprising 27 winter and 24 spring barley cultivars were sown in the autumn and spring of 1990-91. A third nursery was sown with spring barley only in the spring of 1991. The nurseries were inoculated with one of the three following isolates of P. hordei.

Isolate		Race octal	BRV - factors
BRS-90-15	ex. Marinka, Kent	1653	1,2,4,6,8,9,10
BRS-76-12	ex. Varunda, Dyfed	677	1,2,3,4,5,6,8,9
Unknown	Unknown	11	1,4

Results

Higher levels of disease built up on the susceptible winter barley cultivars within the nursery inoculated with race octal 1653 than that into which race octal 677 was introduced. Brown rust sampled from the spreader cultivar within the two nurseries towards the end of the season identified contamination with race octal 1673. The winter barley cultivars (Table 5) displayed a range of quantitative responses to both isolates which appear to be of a generally non-specific nature. Cultivar rankings between nurseries followed a similiar pattern. As in recent years, high levels of naturally occurring inoculum resulted in contamination of the spring barley field isolation nurseries with Triumph-virulent pathotypes (BBV-10). Interpretation of results has thus been made difficult, particularly for the newly introduced cultivars. The lack of recent informative data has meant that placing the spring barley cultivars into groups on the basis of their specific resistances is not possible in 1991. The cultivars have instead been grouped on the basis of similarities in their patterns of response to the three isolates (Table 6).The resistance of cvs Derkado, Forester, Decor, Chad, and Corniche was effective against the field isolates although quantitative differences were apparent. Cv. Simon (BBR-3) was resistant to race octal 1653 and race octal 11, but susceptible to isolate BRS-76-12 which carries the corresponding virulence gene (BBV-3). Field isolation nursery tests in 1989 suggested that cv. Alexis also carries the resistance factor BBR-3 although data from the1991 tests do not confirm this.

Table 5. Percent infection* of winter barley cultivars with specific isolates of P. hordei Otth. in field isolation nurseries in 1991

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)
Clarine	(4)	26	13
Target	(6)	21	8
Posaune	(6)	21	13
Melusine	(6)	19	10
Pipkin	(6)	19	10
Magie	(5)	18	10
Kira	(6)	18	8
Pastoral	(6)	18	8
Torrent	(4)	18	4
Poacher		16	9
Blanche		15	8
Halcyon	(6)	15	7
Maya		14	7
Marinka	(6)	14	6
Gypsy	(7)	14	5
Finesse	(5)	14	3
Manitou		13	8
Shire		13	8
Frolic	(6)	13	6
Eagle		12	4
Gaulois	(6)	11	6
Bronze	(7)	9	3
Puffin	(8)	8 MS	3 MS
Fighter	(7)	6	4
Bambi		6	3
Firefly	(8)	6	2
Karisma		3	1

* Mean of 4 replicates at 3 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 woith specific isolates of P. hordei Otth. in field isolation nurseriesin 1991

Spring 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)	Race octal 11 (BRV-1,4)
Golden promise	52	40	38
Midas	47	42	33
Digger	37	21	20
Hart (4)	32	23	17
Blenheim (4)	42	18	15 MS
Prisma (4)	37	16	9
Nomad (6)	30	20	24
Chariot (6)	27	26	21
Armelle	25	22	10
Dove	19	16	14
Triumph (5)	22	8	5
Vada	15	11	11
Nugget (7)	27 MS	22 MS	18 MS
Shirley (6)	21 MS	16 MS	12 MS
Tyne	11 MS	10 MS	7 MS
Teal	6 MS	13 MS	10 MS
Alexis (7)	23 MS	24 MR	8 MR
Derkado (7)	21 MR	14 MR	4 MR
Forester (8)	17 MR	7 MR	6 MR
Decor (7)	12 MR	4 MR	2 MR
Dallas	8 MR	2 MR	2 MR
Chad (6)	5 MR	2 MR	2 MR
Corniche (8)	2 MR	1 MR	1 MR
Simon	1	16	Trace

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

RHYNCHOSPORIUM OF BARLEY

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One new virulence combination, BRV-1,2,3,7 (race octal 107), was identified from the 50 isolates of *Rhynchosporium secalis* tested on seedlings in 1991. The resistance of the spring barley cv. Digger remained effective against all isolates. Within the field isolation nurseries the winter barley cultivars displayed a range of quantitative responses to the 2 isolates with some cultivars expressing high levels of resistance. Cvs Armelle (BBR-1) and Osiris (BBR-6) were resistant in the field nurseries although one isolate tested, race octal 77, carries the corresponding virulence factors. The resistance of the spring barley cv. Digger remained effective.

SEEDLING TESTS WITH 1991 ISOLATES

One hundred and eight samples of *Rhynchosporium secalis* were received in 1991 of which 39 were from one trial site in Wales and 36 were from N. Ireland. The infected leaf samples were from a range of winter (56) and spring (52) barley cultivars. The geographic origins of the leaf blotch samples are given in Table 1.

Table 1. Geographic origin of Rhynchosporium samples received in 1991

Location	Number of samples
England (ADAS region)	
East	4
West central	12
South	7
North	2
Wales	45
Northern Ireland	36
Unknown	2

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

Table 2. Differential test cultivars for Rhynchosporium secalis

BBR 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 fron the 1991 survey

No. of isolates	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	Octal vir. des.
11	0	0	0	1	1	0	0	14
8	0	0	0	0	1	0	0	4
9	0	0	0	0	0	0	0	0
6	1	0	0	1	1	0	0	114
6	0	0	0	1	1	1	1	17
4	1	0	0	1	1	1	1	117
2	1	0	0	0	0	0	0	100
2	0	0	0	1	0	0	0	10
1	1	0	0	0	1	0	0	104
1	1	0	0	0	1	1	1	107

1 = susceptible, 0 = resistant

Virulence frequency							
1988	0.81	0	0	0.98	0.98	0.19	0.19
1989	0.54	0.08	0.23	0.92	0.92	0.62	0.62
1990	0.54	0.23	0.30	0.76	0.92	0.23	0.23
1991	0.28	0	0	0.52	0.74	0.22	0.22

One new virulence combination was identified in 1991. Isolate RS-91-76, which was identified as race octal 107, differs only from the commonly found race octal 117 in that it lacks virulence to cv. Igri (BBR-4). Cv. La Mesita (BBR-5) was resistant to all isolates as was cv. Pipkin. This decrease in frequency of virulence to cv. La Mesita which carries the same resistance gene Rh4 is a reflection of the failure of the low number of samples received from the winter barley cv. Pipkin in 1991 to culture.

The resistances of cv. Osiris (BBR-6) and the spring barley cv. Digger were effective against all the isolates. The erosion of the resistance carried by cv. Digger observed in 1990 was not confirmed in tests with the 1991 isolates.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Thirty-two winter and 24 spring barley cultivars were sown in each of 2 nurseries in the 1990-91 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-91-72	BRV - 0	0

The nursery inoculated with isolate RS-91-72 was grown alongside a _Rhynchosporium_ disease nursery used to screen barley material and which is infected naturally with race octal 0. 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 low levels of infection were recorded on cvs Athene, Astrix and Igri. A field nursery comprising of the same 24 spring barley cultivars together with the winter barleys Athene, Astrix, Igri and Pirate was sown in the spring of 1991 at the

Scottish Crop Research Institute, Invergowrie, Dundee (Dr. A.C. Newton) and the nursery became infected with naturally occurring inoculum. Isolates cultured from infected leaf samples from this nursery during April and June were identified as race octal 14 (BRV-3,4).

Results

Reasonable levels of disease built up within both winter barley nurseries. Slightly higher levels of Rhynchosporium infection were recorded on the susceptible cultivars within the nursery inoculated with isolate RS-91-72 (BRV-0). The cultivars displayed a range of quantitative responses within both nurseries with cultivar rankings between nurseries following a similar pattern (Table 4). Several of the winter barleys expressed good levels of resistance to both isolates.

Disease levels on the susceptible spring barley cultivars within the nursery inoculated with isolate RS-91-72 were much higher than in the nursery inoculated with the widely virulent race octal 77 (Table 5). Cultivars expressed quantitative differences in susceptibility to both isolates.

The specific resistances of cvs Armelle (BBR-1) and Osiris (BBR-6) were effective against both isolates although isolate RS-85-50 carries the corresponding virulence factors. Very low levels of infection were observed on cv. Digger (BBR-?).

High levels of Rhynchosporium infection were achieved on the susceptible cultivars within the nursery grown at SCRI, Dundee. The resistances carried by cvs La Mesita (BBR-5), Armelle (BBR-1), Osiris (BBR-6) and Digger (BBR-?) were effective against the naturally introduced isolate, race octal 14, which does not carry the corresponding virulence factors.

Table 4. Percent infection* of winter barley cultivars in Rhynchosporium isolation nurseries in 1991

Cultivar (NIAB rating)		RS-91-72 BRV-0	RS-85-50 BRV-1,2,3,4,5,6
Maris Otter		16	12
Posaune	(6)	11	10
Shire		10	5
Bronze	(7)	8	4
Poacher		7	5
Fighter	(6)	6	6
Athene		6	5
Frolic	(7)	6	4
Puffin	(7)	6	3
Pipkin	(7)	6	3
Halcyon	(8)	6	1
Blanche		5	2
Igri		5	2
Clarine	(7)	3	3
Magie	(8)	3	2
Gaulois	(8)	3	2
Astrix		3	2
Gypsy	(8)	3	1
Eagle		2	1
Kira	(8)	2	0.5
Torrent	(8)	2	0.5
Melusine	(8)	1	2
Hoppel		1	1
Pastoral	(8)	1	1
Finesse		1	1
Karisma		1	1
Bambi		1	0.5
Maya		1	0.5
Marinka	(8)	0.5	0.5
Target	(8)	0.5	0.5
Firefly	(8)	0.5	0.5
Manitou	(9)	0.1	0.1

* Mean of 4 replicates, final assessment date
( ) NIAB rating: 1 = susceptible, 9 = resistant

Table 5. Percent infection* of spring barley cultivars in Rhynchosporium isolation nurseries in 1991

Cultivar (NIAB rating)		RS-91-72 BRV-0	RS-85-50 BRV-1,2,3,4,5,6	RS-91-1+ BRV-3,4
Chad	(4)	55	9	34
Forester	(3)	53	7	47
Hart	(5)	50	4	11
Chariot	(5)	48	3	36
Alexis	(3)	41	10	28
Tyne		38	3	16
Decor	(5)	36	7	15
Derkado	(5)	36	6	56
Shirley	(3)	31	1	24
Nugget	(5)	28	2	22
Midas		25	1	9
Prisma	(3)	21	4	19
Dove		21	2	14
Golden Promise		19	5	13
Dallas		16	3	12
Proctor		15	0.5	7
Triumph	(4)	11	2	14
Blenheim	(4)	11	2	18
Nomad	(4)	10	3	25
Teal		10	2	31
La Mesita		3	7	3
Armelle		2	0.5	1
Digger		0.2	0.5	0
Osiris		0	1	0

* Mean of 4 replicates, final assessment date
+ Mean of 4 replicates, 3 assessment dates
( ) NIAB rating: 1 = susceptible, 9 = resistant

NET BLOTCH OF BARLEY

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Virulence to 11 of 13 differential cultivars was detected in 15 isolates of *Pyrenophora teres* Drechs. tested on seedlings. Isolates carried between 1 and 7 specific virulences in various combinations. The frequency of virulence to cv. Marinka was at a reduced level in 1991. In a field isolation nursery, spring barley cultivars displayed a range of quantitative responses to the widely virulent isolate BNS-90-3.

GLASSHOUSE SEEDLING TESTS WITH 1991 ISOLATES

Twenty nine leaf samples of net blotch were received, all from winter barley cultivars. Spore suspensions prepared from the samples were inoculated onto seedlings of the 13 differential cultivars (Table 1), together with 11 additional winter barley cultivars from the NIAB Recommended List and Recommended List Trials.

Results

Fifteen of the isolates were successfully tested. The frequencies of individual virulences corresponding to resistance factors in the differential cultivars together with virulence frequencies over the period 1985-1990 are given in Table 1.

Virulences compatible with the resistance factors in the 13 differential cultivars have been identified previously, although the frequencies of virulence to some of the individual cultivars have fluctuated from season to season. Virulence to Tenn. 61-119 and CI 9518 was again carried by the majority of the isolates whilst cvs CI 5401, CI 6311, CI 9820 and CI 4795 remained resistant to most.

The virulences identified occurred in various combinations in the different isolates, giving a range from the single virulence factor BNV-11 in one isolate, to the more complex and virulent BNV-4,6,8,9,10,11,13 and BNV-2,6,8,10,11,12,13 (Table 2).

The frequency of virulence to the winter barley cv. Marinka has shown a decline in recent years (67% in 1988, 54% in 1989) since it was first detected in 79% of the isolates in 1987. The trend was continued in 1991 with only 25% of the isolates carrying virulence compatible with this cultivar.

Of the other winter barley cultivars included in seedling tests, cv. Chestnut was susceptible to 81% of the 1991 isolates. The remaining cultivars displayed a range of responses with only 1 isolate carrying virulence to cv. Willow.

Table 1. Virulence frequencies (%) corresponding to each differential cultivar (UK CPV Surveys 1985-1991)

Code Number	Cultivar	1985	1987	1989	1991
1	C.I. 5401	14*	0	7	0
2	C.I. 6311	21	0	0	13
3	C.I. 9820	56*	0	7*	0
4	C.I. 739	33	20	7	31
5	C.I. 1243	42	0	57	13
6	C.I. 4795	0	10	14	13
7	C.I. 4502	0	0	14	19
8	C.I. 4979	33	0	7	38
9	Proctor	90	30	93	56
10	Code 65 (W)	7	0	14	31
11	C.I. 9518 (W)	90	90	93	88
12	Tenn. 61-119 (W)	33	60	64	75
13	C.I. 9214	0	0	7*	19
No. of isolates tested		15	24	14	15

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

Table 2. Virulence combinations identified in 1991 isolates

Sample no.	Cultivar and location sampled		Virulence combinations
BNS-91-2	Gaulois,	Trumpington, Cambs.	4,6,8,9,10,11,14
BNS-91-3	Concert,	Raisonmour, Cambs.	4,5,8,9,11,12
BNS-91-5	Firefly,	Northumberland	7,9,11,12
BNS-91-7	Poacher,	Northumberland	9,11,12
BNS-91-9	W. Barley,	Somerset	4,7,8,10,13
BNS-91-11	Gaulois,	Clacton-on-sea, Essex	2,6,8,10,11,12,13
BNS-91-12	Puffin,	Great Maplestead	9,11,12
BNS-91-13	Marinka,	Sudbury, Suffolk	7,8,9,11,12
BNS-91-14	W. Barley,	Bristol, Avon	2,5,8,9,11,12
BNS-91-18	Plaisant,	Dorking, Surrey	5,9,11,12
BNS-91-20	Marinka,	East Grinstead	4,5,11,12
BNS-91-21	Plaisant,	Sheerness, Kent	10,11,12
BNS-91-26	Torrent,	Forthampton, Glous.	4,9,10,11,12
BNS-91-27	W. Barley,	Unknown	11
BNS-91-28	Plaisant,	Chiltern Street, Suffolk	11,12

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Twenty-seven winter and 20 spring barley cultivars were sown in a single nursery in 1990-1991. The nursery was inoculated throughout the season with spore suspensions of isolate BNS-90-3, a widely virulent isolate carrying virulence factors 2,4,5,8,9,10,11,12. This isolate also carries virulence to cv. Marinka.

Results

Net blotch built up on the spreader cultivar in the winter nursery although it was late in the season before reasonable levels were achieved. Little or no disease was observed on the tester cultivars reflecting;

1) the difficulty in achieving high levels of net blotch infection in field nurseries
2) the high levels of resistance in currently grown winter barley cultivars (NIAB Recommended List of Winter Barleys 1992).

No assessments of net blotch infection were made on the winter barley cultivars. Reasonable levels of disease were achieved on the susceptible cultivars within the spring barley nursery. The cultivars displayed a range of quantitative responses to the introduced isolate (Table 3).

Table 3 Percent infection* on spring barley cultivars inoculated with Pyrenophera teres in a field nursery in 1991

Cultivar	BNS-90-3 (2,4,5,8,9,10,11,12)
Blenheim	12
Prisma	11
Tyne	11
Alexis	8
Decor	8
Chariot	7
Digger	6
Forester	5
Chad	4
Nomad	4
Dove	3
Triumph	3
Teal	3
Midas	3
Golden Promise	3
Dallas	3
Derkado	2
Hart	1
Nugget	0.5
Shirley	0.5

* Mean of 4 replicates, final assessment date.

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

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Of 203 infected samples received in 1991, 49% contained barley yellow mosaic virus (BaYMV) and 63% barley mild mosaic virus (BaMMV). As in previous years, BaMMV was more frequent on malting cultivars (Maris Otter, Halcyon, Pipkin and Puffin) whereas BaYMV predominated amongst cultivars used for feed. Six new outbreaks of BaYMV were reported from cultivars previously regarded as immune bringing the UK total to 12.

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. Because the diseases are soil-borne and persist in soil for many years, disease patterns would be expected to change much more slowly than with the air-borne fungus diseases. However a knowledge of the variation in these viruses and of their interaction with barley genotypes is likely to become increasingly important especially in areas where winter barley is grown intensively and the diseases are most widespread. The viruses have a similar particle morphology, cause similar symptoms, are both transmitted by the root infecting fungus *Polymyxa graminis*, and can occur together in the same plant. They are, however, not serologically related and also differ in other properties, including cultivar response. 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.

METHODS

Samples with symptoms were received from winter to early summer (29 January to 25 June), mostly from MAFF CSL Harpenden Laboratory and directly from ADAS regional offices. Leaves were tested by enzyme-linked immunosorbent assay (ELISA) for the presence of both viruses as described by Adams (1990).

RESULTS AND DISCUSSION

The numbers of positive samples received in 1991 (203) was much larger than in previous years (mean 59, see Adams, 1990). This increase occurred with both viruses but especially with BaMMV which was, for the first time, the more frequent virus (in 63% of samples, compared to 49% with BaYMV). For the 139 samples of which the cultivar was known, BaMMV was again the predominant virus on the malting cultivars with Maris Otter parentage (including Halcyon, Pipkin and Puffin). A small number of samples contained both viruses (Table 1). It is likely that the reasons for this big increase are related to the very cold weather in February stimulating symptom production in the following weeks and the cool spring and early summer that favoured the prolongation of symptoms. In other recent years there has been a succession of mild winters, and while symptoms have appeared earlier they have persisted for shorter periods. The increased popularity of Puffin, in which symptoms of BaMMV were often very striking and associated with chocolate coloured necrosis, may also have led to an increase in awareness of the disease.

Table 1. Mosaic virus samples from 1991, classified by cultivar

	Virus(es) detected		
	BaMMV alone	BaYMV alone	Both
Malting cultivars			
Halcyon	15	0	0
Maris Otter	4	0	0
Pipkin	15	1	1
Puffin	36	3	3
Malting Subtotal	70	4	4
Feeding cultivars			
Frolic	1	2	2
Gaulois (R)	0	1	0
Gypsy	1	0	0
Igri	0	4	0
Kira	0	3	0
Magie	0	4	1
Marinka	4	13	3
Mimosa (R)	0	1	0
Panda	0	2	0
Pastoral	1	2	1
Plaisant	3	7	1
Target (R)	0	1	0
Torrent (R)	0	3	0
Feeding Subtotal	10	43	8
Not known	24	29	11
GRAND TOTAL	104	76	23

(R)= cultivar resistant to the common strain of BaYMV

Six new outbreaks of BaYMV occurred on cultivars previously regarded as immune to both viruses (Gaulois, Mimosa, Target and Torrent). There have now been a total of twelve such reports in the UK since 1988, geographically distributed between Wiltshire and Cambridgeshire. They presumably represent one or more distinct races of the virus able to overcome the single, recessive, resistance gene shared by all the currently available "resistant" European barley cultivars. In Europe generally, such outbreaks are being described as BaYMV-2 but efforts to discriminate between strains except by cultivar response have so far been unsuccessful and it is not known if all these outbreaks are indeed similar. In the absence of any diagnostic test, it is also impossible to know whether any of the outbreaks on the susceptible cultivars are also of the "resistance-breaking" type. Japanese experience suggests that races of the virus with different specific virulences may be expected and resistance genes from East Asian barleys are currently being bred into new cultivars for the European market. This highlights the need to understand the relationship between European and Japanese races, which is the subject of a new field-based project involving NIAB, ADAS and IACR.

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MILDEW OF OATS

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Virulence (OMV-4) to the resistance derived from Avena barbata was detected at an increased frequency (0.73) in 1991. Twenty seven of the isolates combined this virulence with OMV-1, 2, 3 making them capable of attacking all currently grown commercial cultivars. Race 5 (OMV-1, 2, 3) showed a decreased frequency (0.19) compared with recent years. One isolate was identified as race 3 (OMV-1, 2).

SEEDLING TESTS WITH 1991 ISOLATES

Forty-six samples of Erysiphe graminis avenae were received in 1991 of which 33 were from spring oat cultivars and 13 from winter oats. Isolates were successfully cultured from 37 of the samples and tested on a set of differential cultivars (Table 1).

Table 1. Differential cultivars used for isolate testing

OMR Group	Differential cultivar
0	Milford
1	Manod
2	Cc4146
3	9065 Cn6/3/74
4	Cc6490

Results

Details of the mildew samples tested are given in Table 2. The frequency of occurrence of the various virulences detected in 1991 compared with previous years are given in Table 3.

The increasing frequency of race 7 (OMV-1,2,3,4) observed in 1989 (0.15) and 1990 (0.27) was continued in 1991 when the frequency rose to 0.73. This race, together with race 6, carries OMV-4 which overcomes the resistance derived from Avena barbata. This race 7 virulence combination, the most complex detected, had remained at a low frequency in the population since it was identified in 1980. Before 1991 the majority of isolates found to carry OMV-1,2,3,4 were from oat breeding trial sites at the Welsh Plant Breeding Station, Aberystwyth where the corresponding resistance (OMR-4) has been incorporated into breeding lines. However, in 1991, mildew samples of diverse geographic origin were identified as carrying OMV-4 although the corresponding resistance is not currently present in any of the oat cultivars being grown in the UK. The increased frequency of race 7 demonstrates the ability of these complex new virulence combinations to compete satisfactorily with simpler races in the field.

The OMV-4 virulence was also identified in combination with OMV-1,2 in two other isolates (race 6). Thus, altogether twenty nine of the 1991 isolates tested carried virulence factor OMV-4, giving an overall frequency of 0.78. The frequency of race 5 (0.19) which has been the predominant race in recent years showed a sharp decline as a consequence of the increased frequency of OMV-4.

Race 3 (OMV-1,2) which was the predominant race up to 1983, was identified in only one isolate received from cv. Dula sampled at S.C.R.I., Dundee.

Table 2. Locations and cultivars from which viable mildew samples were received and virulences for each sample

Locations	Cultivars	Virulence combination (OMV-)
ENGLAND (ADAS) Region		
North		
Cockle park, Northumberland	Dula	1,2,3,4
West Central		
Harper-Adams, Shropshire	Dula	1,2,3,4
Ross-on-Wye, Hereford	Craig, Image	1,2,4
	Kynon(2)+, Mirabel, Aintree, Breeding Line	1,2,3,4
	Solva, Gerald, Breeding Line	1,2,3
South		
Winterbourne, Wiltshire	Dula	1,2,3
WALES		
Trawscoed, Dyfed	Melys, Edit, Gramena Dula, Keeper, Rhiannon Valiant, Breeding Lines(6)	1,2,3,4
	Breeding line	1,2,3
WPBS, Dyfed	Adamo, Rhiannon, Keeper	1,2,3,4
Morfa Mawr, Dyfed	Dula	1,2,3
	Valiant, Rollo	1,2,3,4
SCOTLAND		
Aberdeen	Dula	1,2,3,4
SCRI, Dundee	Dula	1,2
Kelso	Dula	1,2,3
Edinburgh	Dula	1,2,3,4

+ = value in parenthesis after cultivar name indicates number of samples received of that cultivar

Table 3. Virulence combination frequencies (races) identified from samples received in 1991 compared with previous years races since 1979

Virulence combination	Race	Frequency (% total)							No. of isolates in 1991
		1979	1981	1983	1985	1987	1989	1991	
OMV 1	2	0	0	15	0	0	0	0	0
1,2	3	62	68	77	37	15	0	3	1
1,3	4	0	0	0	0	0	0	0	0
1,2,3	5	38	32	8	46	85	85	19	7
1,2,4	6	0	0	0	4	0	0	5	2
1,2,3,4	7	0	0	0	13	0	15	73	27
No. of isolates tested		8	47	13	24	21	26	37	

CROWN RUST OF OATS

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Three virulence combinations were identified from the 1991 crown rust samples. All had been previously identified in the UK, although only one, race 251, occurs commonly.

Nine samples of oat crown rust were received from a range of winter oat cultivers, two from spring oat cultivars and one from wild oats. Nine 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 1991 with race identified for each sample

Location	Cultivar	Race
ENGLAND (ADAS region)	Solva	275
East	Image, Aintree, Kynon	251
West-Central	Aintree, Mirabel, Kynon, Craig	251
	Cribin	205

Three races were identified (Table 2), each virulence combination having been previously found in the UK. Isolate CRS-91-4 carried virulence to cvs Anthony, Appler, Bond, and Saia. This virulence combination, race 205, was previously detected in the UK in 1971. Race 251, which occurs commonly, was cultured from 7 samples. The remaining isolate tested was identified as race 275 which was last detected in 1983 and carries virulence to cvs Appler, Bond, Ukraine and Saia.

Table 2. Virulence spectra of races identified from the 1991 survey together with virulence frequencies (%) corresponding to each differential cultivar

Differential variety	Race			Virulence frequency (%)
	205	275	251	
Anthony	S	R	R	11
Victoria	R	R	R	0
Appler	S	S	S	100
Bond	S	S	S	100
Landhafer	R	R	R	0
Sante Fe	R	R	R	0
Ukraine	R	S	R	11
Trispernia	R	R	R	0
Bondvic	R	R	R	0
Saia	S	S	S	100
No. of isolates	1	1	7	

R = Resistant
S = Susceptible

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1992

Variety diversification schemes to reduce the spread of mildew in spring barley and yellow rust in winter wheat 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 schemes for mildew of barley and yellow rust of wheat which follow update those in the last Annual Report.

The parallel scheme for mildew of wheat was suspended in 1990, 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 resistance to mildew are available and should be grown whenever possible.

A new scheme for brown rust of wheat has been introduced this year.

Diversification 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 laregly 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).

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Revised March 1992

VARIETAL DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY 1992

The increasing complexity of the barley mildew population has reduced the opportunities for diversification, and the diversification scheme has been revised to show a high risk of spread of mildew between a larger number of diversification groups. In addition, the following changes have been made to the diversification groups themselves:

1. Diversification group 2 (cultivars with BMR9) has been combined with diversification group 1.

2. Diversification groups 5 and 6 have been combined with diversification group 0.

3. Diversification groups 3 and 9 have been combined.

4. Diversification group 13 has been removed from the scheme. Regatta, the only cultivar in this group, is no longer on the NIAB or SAC recommended lists, and occupies less than 1% of the acreage of spring barley in England and Wales and in Scotland.

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).

2) Find this DG number under 'Chosen DG' down the left hand side of table.

3) Read across table to find the risk of mildew spread for each companion DG.

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DG 0

Bronze	(W)
Clarine	(W)
Frolic	(W)
Gaulois	(W)
Gypsy	(W)
Halcyon	(W)
Igri	(W)
Marinka	(W)
Magie	(W)
Melusine	(W)
Panda	(W)
Pastoral	(W)
Plaisant	(W)
Posaune	(W)
Puffin	(W)
Sprite	(W)
Target	(W)
G. Promise	(S)
Triumph	(S)

DG 1

Fighter	(W)
Firefly	(W)
Alexis	(S)
Atem	(S)
Chariot	(S)
Dandy	(S)
Derkado	(S)
Forester	(S)
Hart	(S)
Shirley	(S)

DG 3

Golf	(S)
Klaxon	(S)

DG 4

Pipkin	(W)
Nugget	(S)
Sherpa	(S)
Tyne	(S)

DG 7

Chad	(S)
Decor	(S)

DG 8

Manitou	(W)
Nomad	(S)

DG 10

Kira	(W)
Torrent	(W)

DG 11

Blenheim	(S)
Corniche	(S)
Prisma	(S)

DG 12

Camargue	(S)

(W) = winter variety, (S) = spring variety

	Companion DG								
Chosen DG	**0**	**1**	**3**	**4**	**7**	**8**	**10**	**11**	**12**
0	M	+	M	M	M	M	M	M	M
1	+	+	+	+	+	+	+	+	+
3	M	+	M	M	M	M	M	M	m
4	M	+	M	M	m	M	M	M	M
7	M	+	M	+	M	+	m	M	+
8	M	+	M	M	+	M	+	M	M
10	M	+	M	+	m	+	M	M	+
11	M	+	M	m	M	M	M	M	M
12	M	+	m	M	+	M	+	M	M

\+ = Low risk of spread of mildew
m = Moderate risk of spread of mildew
M = High risk of spread of mildew

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST IN WHEAT 1992

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). (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'**.

DG1

Estica
Hussar
Mercia
Pastiche
Torfrida
Canon(S)
Isis(S)
Tonic(S)
Troy(S)

DG2

Admiral
Apollo
Beaver
Haven
Hornet
Slejpner

DG3

Riband

DG4

Avalon
Galahad

DG5

Tara

DG6

Brock

DG7

Axial
Hereward*
Talon

DG8

Norman
Axona(S)
Baldus(S)

DG0

Alexandria(S)

* = provisional

Chosen DG	Companion DG 1	2	3	4	5	6	7	8	0
1	+	+	+	+	+	+	+	+	+
2	+	**Y**	y	y	y	y	y	**Y**	**Y**
3	+	y	**Y**	y	+	y	y	**Y**	**Y**
4	+	y	y	**Y**	+	y	+	y	**Y**
5	+	y	+	+	**Y**	y	+	y	**Y**
6	+	y	y	y	y	**Y**	+	y	**Y**
7	+	y	y	+	+	+	**Y**	y	**Y**
8	+	**Y**	**Y**	y	y	y	y	**Y**	**Y**
0	+	**Y**	**Y**	**Y**	**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.

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VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF BROWN RUST IN WHEAT 1992

Severe infections may result if brown 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 brown rust. The Diversification Scheme should be used to choose varieties to grow adjacent to one another, and in consultation with the scheme for yellow rust.

Choosing varieties to grow together

1. Select first-choice variety and locate its Diversification Group (DG). (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 brown rust
   B = high risk of spread of brown rust
   b = moderate risk of spread of brown rust
4. Wherever possible choose combinations of varieties marked "+". A combination marked "b" is a lesser risk than one marked "**B**".

DG1	**DG1(contd)**	**DG2**	**DG0**
Admiral	Axona (S)	Apollo	Axial
Apostle	Baldus (S)	Beaver	Brock
Brimstone	Canon (S)	Haven	Galahad
Dean	Troy (S)	Hornet	Longbow
Estica		Tara	Mercia
Hereward			Norman
Hussar			Riband
Pastiche		**DG3**	Talon
Rendezvous			Alexandria (S)
Slejpner		Avalon	Isis (S)
Torfrida		Parade	Tonic (S)

Companion DG

Chosen DG	**1**	**2**	**3**	**0**
1	+	+	+	+
2	+	**B**	b	**B**
3	+	b	**B**	**B**
0	+	**B**	**B**	**B**

Note: Varieties in DG1 have good resistance to brown rust spreading from any variety and can therefore be used to diversify with varieties in all DGs, including others in DG1. Varieties in DG0 are susceptible to brown rust spreading from any variety and therefore do not contribute to diversification.