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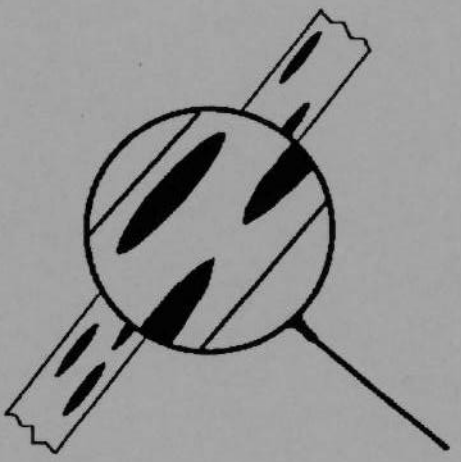
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1995 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 Perdox. The epidemic was the result of the development of increased virulence for this previously resistant cultivar.

OBJECTIVES

The principal objective of the survey is the early detection of increased virulence compatible with resistances 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 throughout the United Kingdom, who collect samples of infected leaves from field crops and cultivar trials and send them 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 in the Annual Report.

The information provided by the Survey is used in several ways. Isolates possessing new virulences are used by the National Institute of Agricultural Botany to evaluate the resistance of cereal cultivars in official trials and 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 by the National Institute of Agricultural Botany and the Scottish Agricultural College.

The UKCPVS is funded by MAFF and HGCA, with a contribution from breeders through fees charged for National List testing.

EXPLANATION OF TERMS USED TO DESCRIBE RESISTANCE AND VIRULENCE

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 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 1995

Mildew of wheat

Virulence factors corresponding to the resistances of current commercial wheat cultivars occurred at high frequencies, with the exception of Vto and Vax. These virulence factors, which correspond to the resistances of Spark and Cadenza, occurred only infrequently on cultivars without the corresponding resistances. The most common pathotype was able to infect all the cultivars on the NIAB Recommended List of Winter Wheats for 1996, except Spark and Cadenza. Virulence for Pm3b and for Pm17, resistances which have not yet been used in the UK, was present at low levels in the population. It seems likely that these virulences would increase if the resistances were used in commercial cultivars. There was no evidence of change in sensitivity to fenpropimorph of the wheat mildew population.

Yellow rust of wheat

Virulence for Yr17, the resistance gene derived from *Aegilops ventricosa* and present in Rendezvous and related cultivars, was confirmed for the first time in an adult plant test. The virulence was also detected in seedling tests of isolates collected during 1995. This change is of great significance to wheat breeding since Rendezvous has been used widely as a parent and many current and potential cultivars depend on Yr17 for their resistance to yellow rust.

Brown rust of wheat

Virulence for a number of previously resistant cultivars, first detected in controlled environment tests in 1994, was confirmed in field tests. An isolate taken from a crop of Chablis infected a number of previously resistant cultivars in controlled environment adult plant tests at 25°C. Seedling tests indicated that the differential cultivars Sterna and Sabre (WBR 7), the spring wheat Chablis and the Thatcher lines Lr3, Lr3bg and Lr3ka, possess a resistance in common.

Mildew of barley

There was little change in the general pattern of virulence in the barley mildew population, with virulences corresponding to common specific resistances recorded at high levels. A few isolates were obtained from *mlo* cultivars, but these failed to infect *mlo* cultivars in subsequent tests and there is no indication of any breakdown of this resistance in the UK. The trend towards increased complexity of pathotypes continued. Tests for sensitivity to fenpropimorph again failed to detect any overall shift, although some isolates showed reduced sensitivity. In Northern Ireland, the frequency of several virulences, both single and multiple, declined compared with the previous season. Although Chad, carrying the *Mla1* resistance gene, occupied a relatively large area, the corresponding virulence remained static. The virulences corresponding to *MlLa*, *Mla13* remained low.

Yellow rust of barley

Yellow rust of barley continues to be rare in the UK. Only three samples were received and all carried the virulence combination BYV 1,2.

Brown rust of barley

Adult plant tests in the glasshouse demonstrated that some cultivars possess specific resistances to brown rust. There were quantitative differences in disease levels between cultivars, indicating that the less susceptible ones have partial resistance (slow rusting).

***Rhynchosporium* of barley**

The spring barley cultivar Digger, which has previously been highly resistant to *Rhynchosporium*, was susceptible at the seedling stage to three isolates collected in 1995. Seedling and adult plant tests in the glasshouse revealed that the spring barleys Brahms and Chieftain carry BRR 5 (Rh4), the resistance also carried by Pipkin. The majority of currently recommended spring barley cultivars are highly susceptible.

Net blotch of barley

The resistance of the differential cultivar CI 5401 remained effective, confirming that it would be valuable to breeders as source of resistance. The majority of recommended winter barley cultivars were susceptible in seedling and adult plant tests in the glasshouse to both a 'netting' and a 'spotting' isolate of the pathogen, although there were quantitative differences in infection levels. A number of spring barley cultivars were resistant to the 'netting' isolate as adult plants, although some of these had been susceptible as seedlings. A wider range of the spring barleys were susceptible to the 'spotting' isolate . This may have been due to a difference in the virulence factors carried by the pathotype. Alternatively it may be that host : pathogen interactions are influenced by the form of the pathogen.

Soilborne mosaic viruses of barley

58 samples were received, 40% of which contained barley yellow mosaic virus (BaYMV) and 86% barley mild mosaic virus (BaMMV). Most samples were of Puffin, on which BaMMV is known to predominate and on which symptoms are often very pronounced. No new outbreaks of resistance-breaking BaYMV were reported.

Mildew of oats

The relatively complex race 5 (OMV 1,2,3), which has increased in frequency in recent years, was the only race identified from the 1995 samples. All the current recommended cultivars of spring and winter oats are seedling susceptible to this race, although some express resistance at later growth stages.

Crown rust of oats

Three previously detected races were identified from the 1995 samples. The majority of currently recommended cultivars of spring and winter oats are highly susceptible to this disease.

MILDEW OF WHEAT

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The results of the 1995 survey were similar to those of the previous year. Most of the virulence factors corresponding to the resistance factors of the current winter wheat cultivars occurred at high levels in the population. The predominant pathotype was able to infect all the cultivars on the NIAB Recommended List of Winter Wheats for 1996, except Spark and Cadenza.

INTRODUCTION

Early mildew infection levels on winter wheat were low in 1995. March was cold and wet, with snow at the beginning of the month in East Anglia. April and May, however, were drier than the previous two years, with temperatures near average in April but higher in May. This encouraged growth of mildew, which reached high levels in some areas of the country, but hot weather in the latter part of June subsequently curtailed disease development.

METHODS

A total of 235 samples of wheat mildew were received in 1995, mostly from trial plots. 265 single colony isolations, taken from 145 samples, were tested. They were collected from the following cultivars:

Cultivar	No. of isolates		No. of isolates		No. of isolates
Caxton	14	Buster	10	Brigadier	10
Charger	9	Dynamo	5	Hussar	10
Genesis	9	Beaver	4	Turpin	9
Hereward	3	Encore	3	Tonic	2
Prophet	10	Haven	7	Spark	7
Rialto	4	Hunter	9	Cadenza	17
Galahad	2	Raleigh	14	Reaper	9
Flame	7	Beaufort	3	Soissons	10
Talent	1	Chianti	18	Crofter	3
Mercia	3	Consort	10	Ritmo	6
Boxer	2	Magellan	13	Shango	2
Slejpner	2	Rendezvous	2	Vivant	4
Apollo	6	Riband	6		
Total	265				

Isolates from a further 46 samples, collected from established cultivars of known resistance, were not tested and 44 samples failed to produce viable conidia.

The samples were collected from the following locations:

	No. of isolates		No. of isolates
Wye, Kent	12	Bittinghay, Lincs.	2
Bridgets, Hants.	61	Long Sutton, Lincs.	20
Abington, Cambs.	23	Rothwell, Lincs.	18
NIAB, Cambridge	35	Headley Hall, Yorks.	16
Ely, Cambs.	8	Cockle Park, Northumb.	1
Woolpit, Suffolk	3	Crichton Royal, Scotland	10
Morley, Norfolk	27	East Lothian, Scotland	26
South Walsham, Norfolk	2	Aberdeen, Scotland	1
Total	265		

Isolates were tested on detached leaf segments of the differential cultivars shown in Table 1 and assessed for virulence on a 0-4 scale for infection type, based on the scale of Moseman *et al.*, (1965).

Table 1. Differential cultivars used to determine virulence factors in isolates of wheat mildew in 1994.

Differential cultivar	European code	Resistance genes	WMR group
Cerco	none	None	0
Galahad	Pm2	*Pm2*	2
Chul	Pm3b	*Pm3b*	3b
Armada	Pm4b	*Pm4b*	4
Hope	Pm5	*Pm5*	5
Flanders	Pm5	*Pm5*	5
Brimstone	Pm2, Pm6	*Pm2, Pm6*	2,6
Clement	Pm8	*Pm8*	7
Maris Dove	Mld	*Mld*	9
Brock	Pm2, MlTa2	*Pm2*, Unknown	2,'Talent'
Mercia	Pm5, MlTa2	*Pm5*, Unknown	5,'Talent'
Tonic	MlTo	Unknown	p
Broom	MlBr	Unknown	q
Sicco	Pm5, MlSi2	*Pm5*, Unknown	5,r
Wembley	MlSo	Unknown	'Sona'
Axona	MlAx	Unknown	'Axona'
Cadenza	MlAx (Mld, MlBr?)	Unknown	'Axona' (+9, q?)
Amigo	Pm17	*Pm17*	10

RESULTS

Virulence frequencies

Table 2 shows the frequencies of wheat mildew virulence factors recorded in 1995, together with those from 1990 to 1994. The high levels of virulence for factors V2, V4b, V6 and V8 observed in earlier years were maintained. Selection for these factors has been present for several years, since the majority of commercial cultivars have carried the corresponding resistance. Virulence for resistance factors Pm5 and MlTa2 was again recorded at a high level. These virulence factors still occur frequently in the population, combined with virulences matching the resistance factors of commonly grown cultivars. As there is little selection for these virulences now, their continued presence is probably a case of 'hitch-hiking'. The frequency of virulence factor Vd was similar to the previous two years.

Table 2. Frequency of wheat mildew virulence factors in isolates from infected leaves collected in 1990, 1991, 1992, 1993. 1994 and 1995.

	Frequency of virulence factors (%)					
Virulence factor	1990	1991	1992	1993	1994	1995
2	99	100	99	98	99	99
3b	-	-	-	-	-	4
4b	52	69	73	79	84	88
5	-	92	90	95	92	92
6	69	80	76	78	80	89
8	66	80	86	93	93	95
d	-	-	27	15	20	19
2,Ta2	-	54	60	80	82	85
To	-	9	24	18	24	18
Br	-	-	31	20	27	21
5,Si2	-	38	32	39	26	22
So	-	-	23	22	21	10
Ax	-	10	17	10	14	11
17	-	-	-	-	-	10
Number of isolates tested	290	300	194	356	347	265

The levels of virulence for MlTo, MlBr and MlAx have decreased slightly, returning to levels similar to those recorded in 1993. There does not, therefore, appear to be a trend towards increased virulence for these resistance factors, which correspond to the resistance of Spark (MlTo) and Cadenza (MlAx). Again, in 1995, all the isolates with virulence for Axona and Cadenza also carried Vd and VBr but it is not clear whether these cultivars carry MlAx or MlBr.

The frequencies of V5,Si2 and VSo continued to decline. There is probably little selection for these virulence factors as MlSo and MlSi2 only occur in some spring cultivars.

Chul (Pm3b) and Amigo (Pm17) were included in the differential set of cultivars in 1995. Following a field experiment in 1990, these two factors were identified as possible useful sources of mildew resistance in wheat (Brown *et al.*, 1991). Isolates were last screened routinely for virulence to Chul in 1975 (Wolfe & Wright, 1976) although some isolates were tested with Chul in 1989 (Brown *et al.*, 1990). During the 1970's, the frequency of V3b was very low, and as the resistance factor Pm3b was not present in any commercial cultivars nor being used in breeding programmes, Chul was omitted from the differential set. As Pm17 has not been used in commercial cultivars in the U.K., Amigo was not previously included in the differential set. Although there has been no selection for V3b and V17, they are present in the population, albeit at a low frequency (4% and 10% respectively). It seems likely, therefore, that neither Pm3b nor Pm17 will provide adequate, long-term protection from wheat mildew, but should be combined with good non-specific resistance.

Table 3. Frequencies of the most commonly identified pathotypes in 1992-1995 as defined by the differential cultivars in Table 1, omitting Chul and Amigo.

	Frequency of pathotypes (%)			
Pathotype *	1992	1993	1994	1995
4b,5,6,8	14	6	8	8
4b,5,8,Ta2	2	4	4	2
4b,5,6,8,Ta2	8	25	26	38
4b,5,6,8,Ta2,To,Br	3	4	5	6
4b,5,6,8.Ta2,Si2	0	0	2	4
4b,5,6,8,Ta2,Si2,So	4	8	6	8
4b,5,6,8,d,Ta2	2	2	7	5
4b,5,6,8,d,Ta2,To,Br,Ax	3	2	3	3
Number of pathotypes	78	78	71	57
Number of isolates	194	356	347	265

* All pathotypes also carry V2

There appears to be a trend towards reduced heterogeneity in the wheat mildew population. Table 3 compares the most commonly occurring pathotypes in 1992, 1993, 1994 and 1995. The total number of pathotypes identified has decreased during these four years. The pathotype 2,4b,5,6,8,Ta2 now predominates, accounting for 38% of the isolates tested in 1995. This pathotype is capable of infecting the cultivars on the NIAB Recommended List of winter wheats except Spark and Cadenza.

Table 4 shows the proportion of the wheat mildew population screened in 1995 which is able to infect the cultivars on the NIAB Recommended List of winter wheat cultivars for 1996.

Table 4. Proportion of mildew isolates tested in 1995 able to infect winter wheat cultivars on the 1996 NIAB Recommended List for (1994 data in brackets).

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Brigadier	80 (76)	Consort	84 (76)
Hussar	80 (76)	Beaufort	85 (76)
Hunter	95 (93)	Dynamo	89 (80)
Riband	84 (76)	Encore	95 (93)
Genesis	100 (100)	Cadenza	11 (14)
Hereward	100 (100)	Flame	88 (84)
Spark	18 (24)	Haven	95 (93)
Mercia	80 (78)	Caxton	100 (100)
Rialto	100 (100)	Reaper	unknown*
Buster	89 (80)	Soissons	unknown*

* the resistance factors of Reaper and Soissons are unknown

Resistance Factors in New Cultivars

The specific resistance factors identified in winter wheat cultivars are shown in Table 6. No new resistance factors or combinations were detected in cultivars tested in 1995.

Table 6. Specific mildew resistance factors of winter wheat cultivars.

None	**Pm2,Pm4b,Pm8**	**Pm4b,Pm6 (Pm2?)**	**MlTo**
Genesis	Apollo	Hussar	Spark
Hereward		Brigadier	
Rialto	**Pm2,Pm6**		**MlAx (Mld,MlBr?)**
Caxton	Buster	**Pm6,Pm8**	Cadenza
Charger	Dynamo	Beaufort	
			Unknown
Pm4b	**Pm2,Pm4b,Pm6**	**Pm4b,Pm6,Pm8 (Pm2?)**	Soissons
Flame	Riband	Turpin	Reaper
	Consort		
Pm8	Chianti	**Pm5,MlTa2**	
Haven	Magellan	Mercia	
Hunter			
Encore			
Raleigh			

Fungicide Sensitivity Tests

A sample of 64 isolates, selected at random from the isolates collected in 1995, were tested for sensitivity to fenpropimorph. The isolates were tested in three batches with the same six control isolates included in each batch. The control isolates were those used in previous years, together with the two least sensitive isolates from 1994. A ring test of European control isolates was carried out in 1995, as part of the COST 817 initiative, and consequently the same doses of fenpropimorph were used for screening the 1995 isolates. The results were expressed as ED50 values, in line with workers in other European countries, but it was not possible to calculate these for the more sensitive isolates. This change in methodology means that 1995 results cannot be directly compared with those of previous years.

Table 7. Sensitivity of 1995 wheat mildew isolates to fenpropimorph.

			Growth as % of growth on untreated leaves				
			Concentration of fenpropimorph, mg/l				
Location	No. of isols.	ED50	4	16	64	128	256
Bridgets	1	-	69	83	31		0
Wye	1	-	72	0	0	0	0
Cambridge	15	92.9	102	84	21	2	0
Ely	4	76.9	102	156	67	7	0
Morley	14	47.7	84	64	22	5	0
S. Walsham	1	55.5	29	57	29	0	0
Long Sutton	7	28.4	91	77	5	0	0
Rothwell	7	41.9	71	76	18	3	0
Crichton Royal	4	185	96	77	53	0	0
East Lothian	10	70.9	95	98	52	15	0
Controls							
Sensitive	3	-	22	1	0	0	0
Insensitive	3	90.7	96	107	69	27	1

The sensitivity of the 1995 isolates and controls is shown in Table 7. Unlike previous years, results of the control isolates in the three batches were remarkably similar and have been combined in the table. The majority of 1995 isolates tested were less sensitive than the sensitive controls, but few were as insensitive as the insensitive controls. The two most insensitive isolates were similar to those found in 1994.

CONCLUSIONS

All the major resistance factors of the current winter wheat cultivars are matched by the corresponding virulence factors in the pathogen population, many of them at near maximum levels. Only the virulence factors VTo and VAx, corresponding to Spark and Axona, remain at relatively low levels. As yet, these factors occur only infrequently on cultivars lacking MlTo and MlAx. New sources of resistance are needed for diversification amongst wheat cultivars. However, most current cultivars have good levels of non-specific resistance, and plant breeders

are urged to continue to exploit this source. There was no evidence of a change in sensitivity to fenpropimorph in 1995.

REFERENCES

Brown, J. K. M., Slater, S. E. & Howe, P. M., (1990). Mildew of Wheat. *U. K. Cereal Pathogen Virulence Survey 1989 Annual Report,* pp. 7-10.

Brown, J. K. M., Mercer, P. C. & Newton, A. C., (1991). Potential sources of resistance of wheat and barley to powdery mildew. *U. K. Cereal Pathogen Virulence Survey 1990 Annual Report,* pp. 52-54.

Mitchell, A. G. & Slater, S. E., (1991). Mildew of wheat. *U.K. Cereal Pathogen Virulence Survey 1990 Annual Report*, pp. 10-14.

Mitchell, A. G. & Slater, S. E., (1992). Mildew of wheat. *U.K. Cereal Pathogen Virulence Survey 1991 Annual Report*, pp. 8-12.

Mitchell, A. G. & Slater, S. E., (1993). Mildew of wheat. *U.K. Cereal Pathogen Virulence Survey 1992 Annual Report*, pp. 8-11.

Moseman, J. G., Macer, R. C. F. and Greely, L. W., (1965). Genetic studies with cultures of *Erysiphe graminis* f.sp. *hordei* virulent on *Hordeum spontaneum*. *Transactions of the British Mycological Society* **48**, pp. 479-489.

Slater, S. E. & Mitchell, A. G., (1994). Mildew of wheat, *U.K. Cereal Pathogen Virulence Survey 1993 Annual Report,* pp. 8-13.

Slater, S. E. & Mitchell, A. G., (1995). Mildew of wheat, *U. K. Cereal Pathogen Virulence Survey 1994 Annual Report,* pp. 8-15.

Wolfe, M. S. & Wright, S. E., (1976). Mildew of wheat, *U. K. Cereal Pathogen Virulence Survey 1976 Annual Report,* pp. 26-32.

YELLOW RUST OF WHEAT

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Virulence for WYR 17 (Yr17) was confirmed for the first time in an adult plant test of an isolate collected in 1994. This virulence was also detected at high levels in seedling tests of isolates collected during 1995.

SEEDLING TESTS OF 1995 ISOLATES

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

Outbreaks of yellow rust in 1995 were largely restricted to traditional high risk areas in the east of the UK. 97 isolates of *P. striiformis* were tested for virulence on seedlings of the differential cultivars listed in Table 1. The isolates originated from 47 different cultivars. 83 isolates were from naturally infected plots or crops and 14 from inoculated plots.

Seedling virulence frequencies, based on isolates from naturally infected crops and plots, are given in Table 2. The frequencies of WYV 1, WYV 2, WYV 3 and WYV 9 remained at, or close to, 100%. WYV 4 and WYV 6 were at intermediate frequencies, with WYV 4 being the more common. Virulence for Brigadier and Hussar was detected in 40% of isolates, a large proportion of which had been collected from infected crops or plots of these and other WYR 17 cultivars.

Table 3 shows the relative frequencies of different pathotypes with virulence for WYR 17 (Rendezvous, Brigadier and Hussar). All pathotypes possessed virulence for WYR 9, providing confirmation that Brigadier and Hussar, the main source cultivars for WYR 17 virulent isolates, possess WYR 9 in combination with WYR 17. The most common pathotype was WYV 1,2,3,9,Re,Br,Hu, with or without virulence for Carstens V and/or Hereward. 28 per cent of the isolates possessed additional virulence for WYR 4, but only one of the WYV 17 isolates possessed WYV 6 and further tests indicated that this isolate was only weakly virulent on WYR 17, giving type 3 reactions.

Table 1. Differential cultivars used in seedling virulence tests in 1995

Differential Cultivar	WYR Factor	Gene	Cultivar Code
Main set			
Chinese 166	WYR 1	Yr 1	
Heines VII	WYR 2	Yr 2	
Cappelle Desprez	WYR 3	Yr 3a + 4a	
Hybrid 46	WYR 4	Yr 3b + 4b	
Heines Kolben	WYR 6	Yr 6	
Tommy	WYR 7	Yr 7	
Compair	WYR 8	Yr 8	
Kavkaz 4 x Federation	WYR 9	Yr 9	
Additional set			
Carstens V	WYR CV		CV
Hereward	WYR CV+		He
Rendezvous	WYR 17	Yr 17	Re
Brigadier	WYR 9+17	Yr 9 + Yr17	Br
Hussar	WYR 9+17	Yr 9 + Yr17	Hu
Cadenza	WYR Rx (Tonic)		Ca
Parade	WYR Rx		Pa
*Lynx	WYR R		Ly

* Not included in all tests

Table 2 Virulence factor frequency % (from naturally infected crops and plots)

Year	'81	'82	'83	'84	'85'	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95
WYV 1	71	63	85	75	76	78	87	68	62	85	91	88	89	65	90
WYV 2	100	100	100	100	100	100	100	100	100	100	100	100	98	100	99
WYV 3	95	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 4	29	37	20	31	45	70	47	78	97	91	86	86	89	86	67
WYV 6	31	29	26	64	90	96	89	72	57	69	64	88	68	41	35
WYV 7	5	5	0	3	3	22	8	6	2	9	19	7	8	4	0
WYV 8	0	2	0	0	*	*	*	*	*	*	0	0	0	0	0
WYV 9	5	2	23	31	3	4	5	66	99	94	88	76	84	94	95
Virulence for cultivars in additional set															
Carstens V													75	55	31
Talon											41	38	60	55	
Hereward											36	47	35	10	36
Rendezvous														57	70
Brigadier												40	35	10	40
Hussar											12	29	32	6	40
Tonic												1	2	0	
Cadenza												0	2	0	0
Parade												3	0	0	0
Lynx															1
No. of isolates	42	41	63	36	29	23	52	71	156	67	42	77	63	49	83

Table 3. Frequency % of pathotypes virulent on the WYR 17 cultivars Rendezvous, Brigadier and Hussar (40 isolates from naturally infected and inoculated plots)

WYV 1,2,3,9,Re,Br,Hu	43
WYV 1,2,3,9,Re,Br,Hu,CV/He	28
WYV 1,2,3,4,9,Re,Br,Hu	20
WYV 1,2,3,4,9,Re,Br,Hu,CV/He	8
WYV 1,2,3,4,6,9,Re,Br*,Hu*	2

* = weakly virulent, type 3 reaction

ADULT PLANT TESTS OF 1994 ISOLATES

14 isolates from the 1994 survey (Table 4) and a mixture of the remaining 1994 isolates were tested for virulence on adult plants of 27 cultivars in Polythene tunnels and on seedlings of the same cultivars. The isolates were chosen on the basis of their seedling virulence characteristics and source cultivar. The cultivars were selected to represent important sources of resistance currently being utilised in breeding programmes.

Table 4. Isolates of *Puccinia striiformis* used in adult plant tests

Isolate code	Source		WYV Factors	Additional virulence*
	Cultivar	Location		
94/519	Hussar	Poly tunnel test	1,2,3,9	Re,Br,Hu,CV,He
94/514	Haven	Poly tunnel test	1,2,3,4,6,7,9	Re,To,Ca
94/48	Hussar	Lincs	1,2,3,4,6,9	Re,Br,Hu,He
94/505	Brigadier	Poly tunnel test	1,2,3,4,6,9	Re
94/515	Hereward	Poly tunnel test	2,3,4,6	CV,Ta,He,Re
94/518	Hereward	Poly tunnel test	2,3,4,6	CV,Ta,He
94/6	Axona	Cambs	1,2,3,4,6	CV,Ta
94/16	Axona	Cambs	1,2,3,4,6,9	Re
94/23	Encore	Cambs	1,2,3,4,6,9	CV,Ta
94/29	CPB W19	Lincs	1,2,3,4,9	CV,Ta
94/502	Haven	Poly tunnel test	1,2,3,6,9	To,Ca,Re
94/510	Hussar	Poly tunnel test	1,2,3,9	Re,Br,Hu,Ta
94/521	Encore	Poly tunnel test	1,2,3,4,6,9	CV,Ta,He,Re
94/522	Hunter	Poly tunnel test	1,2,3,4,6,9	CV,Ta

* cultivar codes as in Table 1 with addition of Ta=Talon; To=Tonic

Adult plant polythene tunnel test results are given in Table 5

Rendezvous, Hussar, Brigadier, Turpin, Beaufort, Chianti, Torfrida and Prophet, cultivars which have previously been resistant as adult plants, were susceptible to isolate 94/519. These cultivars, also gave clear type 4 reactions to 94/519 in seedling tests. It is concluded that they possess the resistance gene Yr17 (WYR 17), derived from *Aegilops ventricosa* and present in the cultivars VPM 1 and Rendezvous, which have been widely used in breeding programmes. This was the first confirmation from adult plant tests of the breakdown of the WYR 17 resistance.

Prophet, although susceptible to a wide spectrum of isolates at the seedling stage, previously had effective adult plant resistance. However, this too was overcome by 94/519 and it appears that Yr17 may be expressed only at the adult stage in this cultivar.

Magellan, a sister line of Chianti, was resistant to 94/519, and it is hypothesised that this cultivar has additional specific resistance, probably WYR 6, derived from the Haven sister line in its parentage. Combined virulence for WYR 6 and WYR 17 has yet to be firmly identified.

Three additional cultivars with WYR 17 in their pedigrees were transplanted into pots and placed in the tunnel infected with 94/519. Two of these, Andante and Reaper proved to be susceptible. The third, Lynx, remained resistant and it is concluded that, like its sister line Magellan, it possesses additional resistance, which may be WYR 6.

The adult plant resistance of Apostle, which is probably present in Hunter and Encore, remained effective, as did the resistance of Parade, which is likely to be present in Dynamo and Buster. The resistances of Axona, Tonic and Cadenza also remained effective.

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. 1. Establishment of a set of type varieties for adult plant tests. *Journal of the National Institute of Agricultural Botany*, **16**, 469-476.

Table 5 **Adult Plant tests 1995. Mean per cent leaf area infection (mean of 4 assessments)**

	Isolate	94/519	94/514	94/48	94/505	94/515	94/518	94/6	94/16	94/23	94/29	94/502	94/510	94/521	94/522	mix
		Virulence in seedling tests given in Table 4														
Cultivar	**WYR factors**															
Brigadier	9,17	47	5	1	0	0	tr	0	tr	tr	0	0	0	0	0	0
Hussar	9,17	19	0	0	0	0	0	0	0	tr	tr	0	1	0	tr	0
Rendezvous	17	16	1	0	0	0	0	0	1	0	0	0	0	0	0	0
Turpin	17	34	3	1	0	0	tr	0	tr	tr	0	0	0	tr	tr	0
Beaufort	17	28	2	0	0	0	0	0	0	0	0	0	0	0	0	0
Chianti	17	30	2	0	0	0	0	0	1	tr	0	0	tr	0	0	tr
Torfrida	17	18	2	0	0	1	tr	0	0	0	0	0	tr	0	0	0
Prophet	0 + 17 (AP)	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0
Magellan	R (?17+)	0	0	0	0	0	0	0	0	0	0	0	0	tr	0	0
Carstens V	CV	1	0	3	7	2	6	0	tr	0	0	0	1	tr	0	tr
Fresco	CV	2	tr	6	11	2	13	1	2	0	0	tr	6	tr	tr	tr
Hereward	CV+	2	0	3	9	4	8	tr	1	0	0	tr	1	tr	tr	2
Consort	?CV+	0	tr	0	0	0	0	tr	0	0	0	0	0	0	0	0
Dean	?9+	9	2	tr	tr	0	tr	tr	2	2	1	tr	4	2	1	tr
Squadron	?9+	20	2	2	5	tr	tr	tr	1	5	1	0	12	1	1	3
Apostle	2,6 + APR	0	0	0	0	0	0	0	0	0	0	0	0	tr	0	0
Hunter	6,9 +APR	0	tr	tr	tr	0	0	0	tr	tr	0	0	0	1	tr	0
Encore	?6,9 +APR	tr	1	1	tr	0	0	tr	1	1	tr	0	0	1	1	tr
Raleigh	9/6,9 + APR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Parade	R Parade	0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0
Dynamo	R Parade	0	tr	0	0	0	0	0	0	0	0	0	0	0	0	0
Buster	R Parade	0	0	0	0	0	0	0	0	tr	0	0	0	0	0	0
Flame	Rx + APR	0	0	0	0	tr	0	tr	tr	0	tr	0	0	0	0	0
Charger	6 +?	0	tr	1	2	tr	2	0	tr	0	0	0	1	tr	0	0
Axona	R x	0	0	0	0	0	0	tr	tr	0	0	0	0	1	1	0
Cadenza	R Tonic	tr	0	0	0	0	0	0	0	0	0	0	0	0	tr	0
Tonic	R Tonic	0	tr	0	tr	0	0	0	0	0	0	1	0	0	1	0

Boxes highlight variety x isolate interactions. They have no statistical significance.

BROWN RUST OF WHEAT

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Two isolates cultured from the 1995 brown rust samples overcame the resistance of the differential cvs Sterna (WBR-7), Sabre (WBR-7), the Thatcher lines Lr 3, Lr 3bg, Lr 3ka and the spring wheat cv. Chablis. In field isolation nurseries the resistance previously expressed by some cultivars was overcome by isolate WBRS-94-50.

GLASSHOUSE SEEDLING TESTS WITH 1995 ISOLATES

Fewer samples (19) of brown rust were received in 1995 compared to 1993 (86 samples) and 1994 (54 samples). Of these 14 were from the CSL/ADAS Cereal Disease Survey. The cultivar and geographic origins of the samples are given in Table 1 and Table 2 respectively. One of the samples was from an infected crop of rye, cv. Marlo.

Table 1. Wheat cultivars from which brown rust samples were received in 1995.

Riband	(5)	Charger
Apollo	(4)	Rialto
Soissons	(2)	Brigadier
Hereward		Haven
Consort		Chablis

( ) = number of samples received of that cultivar, where more than one.

Table 2. Geographical origin of 1995 wheat brown rust samples

Location (NIAB region)	Number of samples
South East	14
South West	2
Central	3

Isolates of *Puccinia recondita* were cultured from 18 of the samples and tested on differential cultivars which comprised the standard WBR cultivars, cv. Thatcher backcross lines carrying different Lr resistance factors, and 22 other spring and wheat cultivars from the NIAB Recommended List and Recommended List Trials (Table 3). Plants were grown and inoculated under standard conditions and, following incubation in dew simulation chambers, were transferred to either of 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).

Table 3. Differential cultivars

Standard differential cultivars (WBR-factor)	Thatcher Lr lines	Spring* and winter cultivars	
Clement (1)	Lr 1	Drake	Raleigh
Maris Fundin (2)	Lr 2a	CWW 93/2	CPBW 25
Norman (2)	Lr 3	Scamp*	Crofter
Hobbit (2)	Lr 3bg	Imp*	Charger
Sappo (3)	Lr 3ka	Toledo*	Chianti
Maris Halberd (4)	Lr 9	Video*	Caxton
Gamin (6)	Lr 15	Minx*	Reaper
Sterna (7)	Lr 19	Taffeta*	Encore
Sabre (7)	Lr 24	Promessa*	Magellan
Armada (0)		Chablis*	Madrigal
		Shiraz*	Harrier

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, interactions were classified as susceptible only if that reaction was expressed at both temperatures. The virulence combinations detected and their frequencies compared with the previous six years are given in Table 4. The frequencies of individual virulences over the same period are given in Table 5.

Isolates carrying virulence factors 1, 2 and 6 in combination have been prevalent in recent years. Although it was the most common combination identified from the 1995 isolates it was at a reduced frequency. Conversely simpler isolates carrying either WBV-1,6 or WBV-6 were at an increased frequency.

In recent years the majority of isolates tested have been identified as carrying WBV-1. Isolates carrying this virulence which overcomes the resistance of cv. Clement (WBR-1), increased greatly in frequency from 1989. This was probably a reflection of the deployment of WBR-1 in a number of popular wheat cultivars at that time. Data from recent seedling and adult plant tests suggest that fewer cultivars currently on the NIAB Recommended List carry this resistance factor. The reduced frequency in 1994 and again in 1995 of isolates carrying WBV-1 may be a reflection of this decline.

Showing a similar reduction in frequency are isolates carrying virulence to the WBR-2 group of cultivars (Maris Fundin, Hobbit and Norman). The resistance of these cultivars, which is temperature-sensitive, was ineffective at 10°C to all the 1995 isolates. At 25°C the majority of the isolates induced a mixed reaction, some being classified as susceptible, others as resistant. As in previous years these cultivars were separated on their reactions to certain isolates (Clifford *et al.*, 1982), cvs Hobbit and Norman being more resistant than cv. Fundin.

Table 4. Virulence combinations and their frequencies identified from the 1995 isolates compared with the previous six years

WBV formula	Frequency						
	1989	1990	1991	1992	1993	1994	1995
6	0	0.02	0	0.06	0.04	0.3	0.22
1,6	0	0	0	0	0	0.03	0.11
2,6	0.33	0.27	0.06	0.12	0.09*	0	0.22
6,7	0	0	0	0	0	0.03	0
1,2,6	0.67	0.67	0.82	0.76	0.75*	0.58	0.34
1,3,6	0	0	0	0	0.02	0	0
2,6,7	0	0.04·	0	0	0	0	0
1,2,3,6	0	0	0	0	0.06	0	0
1,2,4,6	0	0	0.06	0	0	0	0
1,2,6,7	0	0	0	0	0.04▪	0.06	0.11
1,2,3,4,6	0	0	0.06	0.06	0	0	0
Number of isolates tested	12	51	18	17	53	39	18

* some isolates did not carry virulence to all three WBR-2 differential cultivars
▪ 1 isolate only carried virulence to cv. Sterna and to cv. Sabre
· isolates not virulent on cv. Sabre at high temperature (25°C)

Table 5. Virulence frequencies corresponding to each differential cultivar (UK CPVS 1989-1995)

Cultivar	WBR factor	Frequency						
		1989	1990	1991	1992	1993	1994	1995
Clement	1	0.67	0.67	0.94	0.82	0.87	0.67	0.55
Fundin	2*	1.00	0.98	1.00	0.94	0.83	0.64	0.67
Norman	2*	1.00	0.98	1.00	0.94	0.94	0.49	0.55
Hobbit	2*	1.00	0.98	1.00	0.94	0.94	0.41	0.44
Sappo	3*	0	0	0.06	0.06	0.08	0	0
Halberd	4*	0	0	0.11	0.06	0	0	0
Gamin	6	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sterna	7*	0	0.04	0	0	0.04	0.08	0.11
Sabre	7*	0	0	0	0	0.02	0.08	0.11
Armada	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of isolates		12	51	18	17	53	39	18

*Temperature sensitive

The temperature-sensitive resistance (WBR-7) of cvs Sabre and Sterna which is effective at 25°C was overcome by 2 isolates. The remaining isolates were virulent on these cultivars at 10°C, with the exception of 1 isolate which failed to infect either of these WBR-7 cultivars.

The resistances of cvs Sappo (WBR-3) and Halberd (WBR-4), which are more effective at the lower temperature, were not overcome by any of the 1995 isolates although several isolates were virulent on them at 25°C.

The reactions of the Thatcher-Lr backcross lines, which carry known specific Lr genes, to the 1995 isolates are given in Table 6.

Table 6 Virulence frequencies corresponding to each Thatcher-Lr backcross lines to 1995 isolates of *P. recondita* at two temperatures, 10°C and 25°C

Reaction Profile		Thatcher Line (Lr gene)								
10°C	25°C	Lr1	Lr2a	Lr3	Lr3bg	Lr3ka	Lr9	Lr15	Lr19	Lr24
R,MR	R,MR		0.48	0.14	0.14	0.31	0.45	1.00	1.00	0.5
R,MR	MS,S									
MS,S	R,MR	1.00	0.54	0.72	0.72	0.55	0.55			0.5
MS,S	MS,S			0.14	0.14	0.14				

R = resistant; MR = mixed resistant
S = susceptible; MS = mixed susceptible

All Lr genes are temperature-sensitive except Lr15 and Lr19 where resistance to all isolates tested was expressed at both high and low temperatures. Virulence to the latter has not been detected in the UK. In those temperature-sensitive lines resistance was observed at the higher temperature with the majority of isolates inducing susceptibility at 10°C. The Lr3 lines reacted similarly to the isolates although resistance conferred by Lr3ka was generally more effective at 10°C. Two isolates overcame the resistances of these 3 lines at both temperatures. Isolates carrying the corresponding virulence have previously been identified at a low frequency in the pathogen population. In previous years Lr24 has been resistant to the majority of isolates at both temperatures. Occasionally isolates have been identified which overcome this resistance at either the low or high temperature. Tests with the 1995 isolates saw the resistance of Lr24 being ineffective to half of these at the higher temperature (25°C).

Of the additional wheat cultivars, Scamp, Imp, Video, Taffeta and Caxton were susceptible to all the isolates. The isolates appear to comprise a mixture of races as the remaining cultivars displayed a range of responses of a generally mixed type. This makes grouping the cultivars on the basis of their reactions to the isolates difficult.

The resistance of cv. Promessa remained effective, although it was susceptible to one isolate at 10°C and to another at 25°C.

Two isolates (one of which was cultured from a heavily infected crop of cv. Chablis) overcame the high temperature resistance of cv. Chablis. These were the isolates which were virulent on cvs Sterna (WBR-7), Sabre (WBR-7) and the Thatcher-Lr3 lines. Cultivar Shiraz, which was also

only susceptible to these two isolates at 25°C, carries additional or different resistance as it was resistant to a number of the isolates at 10°C.

Cultivars Raleigh, Encore and CPW25 showed a similar pattern of responses to the isolates, being susceptible to the same 4 isolates.

Cultivar Toledo has a temperature-sensitive resistance effective against some isolates at the higher temperature.

The majority of the 1995 isolates were virulent on cvs Magellan, Chianti, Charger and Reaper. The resistant responses of these cultivars to some isolates at either one or both temperatures suggest they may carry the same resistance(s).

Resistance conferred by cvs Madrigal, Harrier and Drake was generally effective.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Sixty winter and spring wheat cultivars were sown in each of four nurseries in the 1994-1995 season using standard procedures (Clifford, Jones and Priestley, 1978). The nurseries were each inoculated with one of the following isolates of *P. recondita*.

Isolate	Origin
WBRS-94-50	cv. Flame, Barroway Drove, Norfolk
WBRS-94-16	cv. Soissons, Headley Hall, North Yorks
WBRS-93-84	cv. Buster, Bristol, Avon
WBRS-93-87	cv. Hereward, NIAB, Cambs

Results

These are summarised in Table 7. Disease was slow to build up on the spreader cultivar within the nurseries so it was late in the season before the susceptible test cultivars showed reasonable levels of infection. The majority of the cultivars were resistant to 3 of the isolates with only WBRS-94-50 carrying virulence(s) able to overcome some of these resistances. This isolate was identified as being widely virulent in 1994 controlled environment tests (adult plants) when a number of previously resistant wheat cultivars were classified as susceptible (Jones and Clifford, 1995). Using data from the 1995 nurseries, together with results from previous years' adult plant and seedling tests, the cultivars were classified into groups. It should not be interpreted that cultivars within a group carry a common resistance factor(s).

Group 1: Only isolate WBRS-94-50 infected these cultivars, previously identified as carrying resistance factor WBR-1. Some of the cultivars within this group were susceptible to isolate WBRS-93-87 in the 1994 field isolation nursery but in these tests they were resistant. The basis on which the cultivars are classified into sub-groups has been documented previously (Jones and Clifford, 1995).

Group 2: Cultivar Fundin (WBR-2) displayed quantitative differences in susceptibility to the isolates. The additional resistance carried by cvs Hobbit and Norman (Clifford *et al.*, 1982) was effective to all but isolate WBRS-94-50, although cv. Norman was less heavily infected than either cvs Fundin or Hobbit.

Group 5: Cultivars within this group were susceptible to all the isolates. Certain isolates have previously differentiated cvs Huntsman and Mercia.

Group 6: The adult plant resistance of cvs Gamin and Dynamo was overcome, albeit at low levels, by isolate WBRS-94-50. Cultivar Virtue, shown previously to carry resistance different to that of cv. Gamin, was also susceptible to this isolate.

Group 7: Cultivar Chablis was, as in 1994, susceptible in seedling tests to isolates identified as carrying virulence factor WBR-7. In 1995 field tests it was resistant to isolate WBRS-94-16, which was identified as carrying WBV-7 in seedling tests, but susceptible to WBRS-93-87 which failed to infect cvs Sterna (WBR-7) and Sabre (WBR-7) in previous seedling and adult plant tests. It also failed to infect cv. Chablis in the 1994 field nurseries. These results suggest that either the plots thought to be cv. Chablis within the nursery inoculated with isolate WBRS-93-87 were mistakenly sown with a different cultivar, or that the nursery was contaminated with a Chablis virulent pathotype and that cvs Sterna and Sabre carry a different or adult plant resistance. Cultivar Shiraz (Group 12) which was included within this group in 1994 appears to carry different or additional resistance.

Group 9: As in 1994, cultivars within this group expressed a similar pattern of responses to the isolates. Cultivar Riband which has been susceptible to the majority of isolates against which it has been tested in field nurseries in previous seasons and which has a NIAB disease rating of 4, expressed good levels of resistance to 3 of the isolates. Cultivar Taffeta, which appears to carry adult plant resistance, also expressed resistance to these 3 isolates.

Group 10: Cultivars Spark, Hereward and Consort which are thought to have a specific resistance in common (Jones and Clifford, 1995) were resistant to all four isolates.

Group 10a: The adult plant, low-temperature resistance of cvs Pastiche and Soissons was generally effective. Previous data have suggested they carry the same resistance with cv. Pastiche being infected at lower levels by pathotypes carrying the corresponding virulence factor.

Group 11: The overall resistance of cvs Brigadier and Hussar has been effective in the field, with any brown rust infection being at very low levels. Controlled environment tests of adult plants have identified 2 isolates overcoming this resistance. One of these, WBR-93-56, failed to infect the 2 cultivars in subsequent field tests. The other, WBRS-94-50, introduced into one of the 1995 isolation nurseries, did infect cvs Hussar and Brigadier. Cultivar Beaufort was infected at much lower levels suggesting that it carries additional or different resistance(s).

Group 11a: The resistance(s) of these cultivars was overcome by isolate WBRS-94-50 albeit at low levels. This isolate was cultured from a heavily infected leaf sample of cv. Flame. Adult plant tests in controlled environments in 1994 confirmed this isolate as carrying virulence to cv. Flame. Cultivars Torfrida and Estica were also susceptible in these tests but cv. Cadenza

expressed resistance at the lower temperature regime.

Group 12: Cultivars within this group were more heavily infected within the nurseries inoculated with isolates WBRS-94-50 and WBRS-93-87. Some plants within the plots of cv. Toledo were susceptible whilst others were resistant.

Group 13: Cultivars displayed a mainly resistant response to the isolates, with this resistance having been identified as being of the adult plant type in some of them.

CONTROLLED ENVIRONMENT TESTS

Fifteen winter and spring wheat cultivars were grown in spore-proofed conditions to the flowering stage of growth. Two replicates of each cultivar were inoculated with isolate WBRS-95-19. This isolate was cultured from heavily infected leaves sampled from a plot of cv. Chablis received from a wheat breeding nursery. This cultivar is thought to carry resistance factor WBR-7, virulence to which occurs at very low frequencies in the pathogen population.

Results

These are given in Table 8. Assessments of percentage flag leaf area infected and of reaction type were made 10 days post-inoculation at 25°C and 26 days post-inoculation at 10°C.

Of the cultivars, which were selected on the basis of the high levels of resistance shown in previous tests, only cv. Dynamo gave a susceptible reaction at both temperature regimes. This cultivar, the resistance of which is of the adult plant type, has been resistant to the majority of isolates against which it has been tested in the field.

Several of the cultivars were identified as carrying temperature-sensitive resistance which was effective at 10°C but overcome at 25°C. These included cvs Cadenza and Spark, the resistances of which have been ineffective at 25°C in previous tests with other isolates.

The adult plant resistance of cv. Axona, which has been effective at low and high temperatures in previous controlled environment and field tests, was overcome at 25°C in these tests.

The resistance of cvs Brigadier and Genesis is of the overall type, but has been overcome in controlled environment tests. Both cultivars were susceptible at 25°C although infection levels were relatively low. At 10°C cv. Genesis was resistant with cv. Brigadier displaying infection levels of 1%.

Cultivar Chablis (WBR-7), which was highly susceptible in a field trial infected with a pathotype from which the test isolate WBRS-95-19 was cultured, was also susceptible in these tests. Infection levels were very low at 10°C but higher at 25°C. The levels of infection were lower than expected given the high levels observed on the field plot. These results indicate that cv. Chablis is more susceptible to isolates carrying the corresponding virulence at the high temperature, so the high temperatures of the 1995 summer would have been conducive to the development of rust on this cultivar.

The resistance of cv. Promessa remains effective.

REFERENCES

Clifford, B.C., Nazim, M.M. and Jones, E.R.L. (1982). Brown rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1981 Annual Report, pp.30-36.

Jones, E.R.L. and Clifford, B.C. (1995). Brown rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1994 Annual Report, pp.22-33.

Clifford, B.C., Jones, E.R.L. and Priestley, R.H. (1978). Brown rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1977 Annual Report, pp.22-27.

Table 7. *Percentage infection of wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1995

Cultivar (NIAB rating)		Group	WBR factor	WBRS-94-16	WBRS-94-50	WBRS-93-84	WBRS-93-87
Clement		1	1	Trace	11	Trace	0.1
Haven	(3)	1a	1+	0.5	20	0	0
Apollo			1+	0	19	0	Trace
Beaver			1+	0.1	17	0	Trace
Admiral			1+	0.1	16	0	0.2
Rialto	(3)	1b		Trace	19	0	0
Slejpner		1c	1+APR	0	6	0	0
Zodiac		1d	1+APR+OR	0	3	0	0
Turpin			1+APR+OR	0	7 MS	0	0
Hunter	(8)		1+APR+OR	0	0.6	0	0
Fundin		2	2	9	24	16	5 MS
Hobbit			2+	0.4 MS	21	1 MS	2 MS
Norman			2+	0.5 MS	6	2 MS	0.6 MS
Huntsman		5	5 APR	11	18	18	15
Mercia	(5)		APR	12	12	18	15
Armada			0	5	16	16	14
Gamin		6	6 APR	0	5	Trace	0.2
Dynamo	(7)		APR	0	4	0	Trace
Virtue			APR	0	11 MS	0	0
Sterna		7	7	0	Trace	Trace	Trace
Sabre			7	0	Trace	Trace	Trace
Chablis (S)	(9)		7?	Trace	0.1	2	23
Ranger		8	8 APR	0	1	0	0
Avans (S)	(3)		OR	0	Trace	0	0
Kinsman				0	0.5	0	0

Table 7. (continued)

Cultivar (NIAB rating)		Group	WBR factor	WBRS-94-16	WBRS-94-50	WBRS-93-84	WBRS-93-87
Avalon		9	9(APR)	0	14	Trace	2
Buster	(3)		APR	0	11	0	Trace
Riband	(4)			0.2	13	3 MS	3 MS
Taffeta (S)			APR	0.1	13 MS	0.5	3
Spark	(7)	10	APR	0	1	0	Trace
Hereward	(7)		APR	0	2	0	0
Consort	(6)		APR	Trace	1 MS	0	0
Soissons	(3)	10a	APR	0	0.2	3	3
Pastiche			APR	0	Trace	Trace	0.5
Brigadier	(9)	11	OR?	0	7 MS	0	0
Hussar	(8)		OR?	0	10 MS	0	0
Beaufort	(9)		OR?	0	1	0	0
Cadenza	(8)	11a		0	6	0	0
Torfrida			APR	0.1 MS	4 MS	0	0
CWW91/3				0	5	0	0
Andante				0	3 MS	0	0
Estica			APR	0	2	0	0
Flame	(8)			0	3	0	0
Scamp (S)		12		3	19	4	30
Imp (S)				2	25	4	23
Video (S)				4	29	3	19
Minx (S)				1	9	3	10
Tonic (S)				2	17	5	28
Toledo (S)				Trace	†Mixed	Mixed	Mixed

Table 7. (continued)

Cultivar (NIAB rating)		Group	WBR factor	WBRS-94-16	WBRS-94-50	WBRS-93-84	WBRS-93-87
Genesis	(8)	13	APR	0	0.1	0	0
CWW91/5				0	0.2	0	0
CWW91/1				0	0.6	Trace	0
Encore	(9)		APR+OR	0	1 MS	0	0
Axona (S)	(9)		APR	0	Trace	0	0
Baldus (S)	(7)		APR+OR	0	0.4	0	0
Lynx				0	1 MS	0	0
Prophet				0	0.2	0	0
Shiraz (S)	(9)		APR+OR	0	0	0	0
Promessa (S)	(9)		OR	0	0	0	0.2
Canon (S)	(6)		APR+OR	0	0	Trace	4 MR

* Mean of 3 replicates, 2 assessment dates
All reaction types susceptible unless stated.
MR = mixed resistant; MS = mixed susceptible;
APR = adult plant resistance; OR = overall resistance.
( ) NIAB rating: 1 = susceptible; 9 = resistant;
Cvs in **bold** text are currently Fully Recommended;
(S) = spring wheat;

† Mixed: some plants susceptible, others resistant.

Table 8 †Reactions of wheat cultivars (adult plants) to an isolate (WBRS-95-19) of *P. recondita* at 10°C and 25°C

	Incubation Temperature	
Cultivar	10°C	25°C
CWW91/3	15 MR	25 MR
Flame	10 MR	10 MR
Hunter	5 R	7 MR
Promessa	0	2 R
CWW91/1	0	Trace
Shiraz	1	2
Canon	0	2
CWW91/5	1	3
Genesis	0	5
Chablis	1	7
Brigadier	1	7
Axona	0	15
Spark	Trace	20
Cadenza	0	25
Dynamo	8	10

† Percentage flag leaf area infected ($\bar{x}$ of 2 replicates)
All reactions susceptible unless stated.
MS = mixed susceptible; R = resistant.

BROWN RUST OF WHEAT ADULT PLANT TESTS AT NIAB

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METHODS

Four spreader beds of winter wheat were inoculated with different isolates of wheat brown rust, as part of the Recommended List testing programme funded by the Home-Grown Cereals Authority. The isolates had all been used previously in the 1994 tests (Mitchell, 1995). Details of the isolates are given in Table 1 and the test results are summarised in Table 2.

Table 1. Isolates of wheat brown rust used in adult plant tests, NIAB Cambridge, 1995

Isolate (Probable virulence)	Origin of Isolate
WBRS-91-65 (1,2,3,4,Soissons,Pastiche)	Pastiche, Cambs.,1991
WBRS-91-67 (1,2,Virtue,Buster)	Virtue, Cambs., 1991
WBRS-93-56 (1,2,5,9,Slejpner,Virtue,Buster)	Hunter, Kent, 1993
WBRS-93-84 (2,5,9,Virtue,Buster)	Buster, Avon, 1993

RESULTS

Infection levels produced by the four isolates were generally much lower than those due to the same isolates in similar 1994 tests (Mitchell, 1995). This was probably a result of the hot dry summer of 1995 being unfavourable for brown rust development, despite provision of conducive infection conditions in the artificially inoculated spreader beds. Isolate 93-84 gave the highest levels of infection, affecting about three times as many cultivars as the other isolates. Mercia was the first cultivar to show symptoms and had the highest overall levels.

Isolate 91-65 had virulence for Crofter and, as in 1994, infected Soissons and Pastiche, although disease levels were lower. Isolate 91-67 showed virulence for Beaver and Haven and 93-56 infected both Buster and Virtue, confirming previous results. Isolate 93-84 was virulent on many cultivars, including some of the newer ones, but did not infect Flame, unlike 1994.

Table 2. Reactions of winter wheat cultivars to infection by four brown rust isolates in spreader bed tests, NIAB Cambridge, 1995. (New varieties in *italics*.)

	% Infection with brown rust*			
Cultivar	**91-65**	**91-67**	**93-56**	**93-84**
Galatea	11.5	7	7.5	26.5
Mercia	18	15	18	23
Rialto	6	4	4	11
Riband	2	0.3	0.2	9
Soissons	0.2	0.2	0.2	3.5
Crofter	1.3	0	2	7
Avalon	0.8	0	0	10
Caxton	0.9	0	0	1
Pastiche	0.2	0	0	4
Beaver	0	2	0	9
Haven	0	4	0	3
Buster	0	0	5	8.5
Virtue	0	0	0.8	7.5
Charger	0	0	0	7
Chianti	0	0	0	5
Consort	0	0	0	6
Dynamo	0	0	0	2
Genesis	0	0	0	0.6
Hereward	0	0	0	3
Slejpner	0	0	0	2.5
Spark	0	0	0	2
Beaufort	0	0	0	0
Brigadier	0	0	0	0
Cadenza	0	0	0	0
Encore	0	0	0	0
Flame	0	0	0	0
Hunter	0	0	0	0
Hussar	0	0	0	0
Magellan	0	0	0	0
Prophet	0	0	0	0
Raleigh	0	0	0	0
Reaper	0	0	0	0
Turpin	0	0	0	0

* Mean of two replicates assessed three times

In Table 2, an attempt has been made to group cultivars according to their reactions to infection by four, three, two, one or none of the isolates. Twelve cultivars were resistant to all four isolates and showed some similarity to reactions in tests by Jones and Clifford (1995), with nine cultivars being in their 'resistant" Groups 1d, 11 or 11a. Most cultivars in these groups carry adult plant and/or overall resistance to brown rust.

Virulence to Consort, Hereward and Spark was exhibited by isolate 93-84: these cultivars have also been infected by some isolates previously and are all in Group 10 (Jones and Clifford, 1995). Mercia appears to be increasingly susceptible to current races of brown rust and has a lower disease resistance rating (5) for 1996. Of the two new Recommended List cultivars, Reaper was resistant to all isolates but Caxton was slightly susceptible to 91-65 and 93-84.

REFERENCES

Jones, E.R.L. & Clifford, B.C. (1995). Brown rust of wheat. *U.K. Cereal Pathogen Virulence Survey 1994 Annual Report*, pp.22-33.

Mitchell, A.G. (1995). Brown rust of wheat adult plant tests at NIAB. *U.K. Cereal Pathogen Virulence Survey 1994 Annual Report*, pp.34-35.

MILDEW OF BARLEY

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Virulences corresponding to all widely used specific resistances were recorded at high frequencies. Some isolates were obtained from *mlo* spring barley cultivars but virulence was not detected. The virulence spectrum of the mildew population remains relatively stable, although there is a definite trend towards increasing complexity with pathotypes carrying more virulence factors. This situation needs close monitoring. Amber and Brahms appear to each carry *Mla13* plus different additional resistance, but further tests are needed for clarification.

INTRODUCTION

The aims of the barley powdery mildew virulence survey are to monitor changes in the frequencies and combinations of virulence factors, to determine the specific resistance of new cultivars and to compile the variety diversification scheme.

METHODS

Single colony isolates of barley powdery mildew were obtained from samples of infected leaves, mostly from untreated Recommended List trials. Random samples of airborne spores were collected at NIAB, Cambridge in March, June and October by exposing seedlings of the universally susceptible cultivar Golden Promise on a high roof.

Isolates from infected leaves were collected from the following 10 locations:

Bridgets, Hampshire	57	isolates	Rothwell, Lincolnshire	28	isolates
Wye, Kent	49		Headley Hall, Yorkshire	64	
NIAB, Cambridge	96		Cockle Park, Northumberland	5	
Morley, Norfolk	5		East Lothian, Scotland	9	
Fakenham, Norfolk	17		Aberdeen, Scotland	2	
			Total	332	isolates

The isolates were collected from the following 27 winter and 16 spring cultivars:

Winter cultivars

Halcyon	4	isolates	Angora	9	isolates	Sunrise	12	isolates
Hanna	12		Melanie	6		Puffin	14	
Bronze	2		Target	10		Willow	7	
Intro	7		Prelude	9		Manitou	5	
Linnet	11		Fanfare	11		Pipkin	6	
Muscat	10		Regina	9		Fighter	4	
Pastoral	7		Tempo	8		Gaelic	12	
Sprite	2		Epic	6		Corsar	5	
Tokyo	5		Gleam	8		CPB B7	4	

Spring cultivars

Optic	15	isolates	Nomad	2	isolates	Chieftain	9	isolates
Cooper	14		Chariot	1		Riviera	8	
Brewster	10		Derkado	3		Dallas	2	
Cork	16		Hart	3		Amber	11	
Delibes	16		Juno	2		Brahms	13	
Felicie	2							

A further 25 samples of infected leaves failed to produce viable isolates.

Isolates were tested for virulence on detached leaves of the differential cultivars listed in Table 1. Assessment of virulence was based on the infection types described by Moseman *et al* (1965). The virulence and resistance nomenclature proposed by Boesen *et al* (1994) was adopted in this work, as in most European countries. The corresponding BMV and BMR codes are also given but these are now becoming outdated.

Table 1. Differential cultivars used to determine virulence factors in isolates of barley mildew.

Cultivar	Resistance genes	BMR group
Golden Promise	none	0
Weihenstephan 37/136	*Mlh*	1a
Weihenstephan 41/145	*Mlra*	1b
Goldfoil	*Mlg*	2a
Zephyr	*Mlg, Ml(CP)*	2a, 2b
Midas	*Mla6*	3
Lofa Abed	*MlLa*	4
Hassan	*Mla12*	5
Hordeum 1063	*Mlk1*	6a
Porter	*Mla7*	6b
Lotta	*Ml(Ab)*	6c
Triumph	*Mla7, Ml(Ab)*	6b, 6c
Tyra	*Mla1*	7
Roland	*Mla9*	8
Simon	*Mlk1, Mla9*	6a, 8
Apex	*mlo*	9
Digger	*Mla13*	10a
Ricardo	*Mla3*	11

RESULTS

Virulence

Virulence frequencies corresponding to the resistance genes in the differential cultivars (excluding *mlo*) are shown in Table 2. Results are also given for non-corresponding virulences, where those virulences in individual isolates corresponding to the host cultivar

resistance have been excluded. This gives some indication of the effect of host resistance on virulence frequencies.

Table 2. Virulence frequencies in single colony isolates of barley mildew from infected leaves (leaf sample) and from random samples of airborne spores.

		Frequency of virulence factors (%)				
		Leaf sample		Random samples of airborne spores		
Virulence gene	Virulence factor	All data	Non-corresponding virulence *	March	June	October
Vh	1a	77	72	63	69	44
Vra	1b	100	100	100	100	100
Vg	2a	98	98	87	97	88
V(CP)	2b	92	92	80	95	88
Va6	3	42	35	14	41	18
VLa	4	29	26	20	44	48
Va12	5	79	79	51	74	50
Vk1	6a	70	70	74	75	74
Va7	6b	74	74	70	75	74
V(Ab)	6c	77	72	56	60	30
Va1	7	31	17	7	33	30
Va9	8	33	31	35	29	34
Va13	10	33	31	54	33	38
Va3	11	<1	<1	0	0	1
Number of isolates		332		97	73	50

* Includes virulence factors only where they did not correspond with the host resistance factors

Virulences, eg *Vra, Vg, V(CP),* corresponding to current resistance genes continued to occur at high frequencies. Others, eg *Va6, Vla, Va1, Va9, Va13*, were recorded less frequently, as the corresponding resistances are less widely used in present cultivars. *Va3* remained at a very low frequency: the lack of corresponding resistance in commercial cultivars means that there is no selection for this virulence factor. However, *Va3* is common in Scandinavia and could potentially be a problem in the UK (Dr J Brown, pers. comm.). Seven isolates were obtained from cultivars with known *mlo* resistance, but none were virulent on the *mlo* differential or original cultivar.

Small changes were recorded in the frequency of some virulences compared to 1994, reflecting changes in the proportions of varieties in trials and in commercial use. Thus, *Va6, Va12, VLa, Va7* and *Va1* were recorded at higher levels, but *Vh, V(Ab) and Va13* at lower levels than in 1994.

Results from the last six years' surveys are shown in Table 3 for comparison. The virulence spectrum has remained fairly stable over the last 6 years: the early 1990's showed an increase in the frequency of *Va6* but this now appears to have stabilised. The gradual increase in *Va1* observed in earlier years continued in 1995, as cultivars with the corresponding resistance

increase in popularity. The frequency of *Va9* was similar to 1994, while that of *Va3* remains at a very low level for reasons described above.

Table 3. Virulence frequencies in barley mildew, 1990 to 1995.

Virulence gene	Virulence frequency (%) *					
	1990	1991	1992	1993	1994	1995
Vh	-	-	78	78	79	70
Vra	-	99	100	100	99	100
Vg	-	99	99	96	95	95
V(CP)	-	96	98	92	88	90
Va6	15	23	31	35	31	34
VLa	29	36	24	22	25	31
Va12	64	61	73	72	67	71
Vk1	71	80	77	75	72	72
Va7	74	78	78	76	69	73
V(Ab)	62	64	72	76	74	67
Va1	14	15	13	18	23	27
Va9	16	28	26	29	34	33
Va13	31	43	42	38	43	37
Va3	-	-	-	1	<1	<1
Number of isolates		780	462	628	539	552

* Mean of leaf samples and random samples of airborne spores for each year. Data from Mitchell & Slater (1991, 1992, 1993, 1994,1995).

\- No data

Complexity of isolates

The number of virulence factors carried by isolates in each sample is given in Table 4.Figure 1 shows a comparison of the complexity of isolates collected in the last five years

82% of isolates in the leaf sample carried 7-10 virulence factors, while most isolates in the random sample of airborne spores had 6-9 virulences. There was better agreement between the results of the two sets of samples in 1995 compared to 1994.

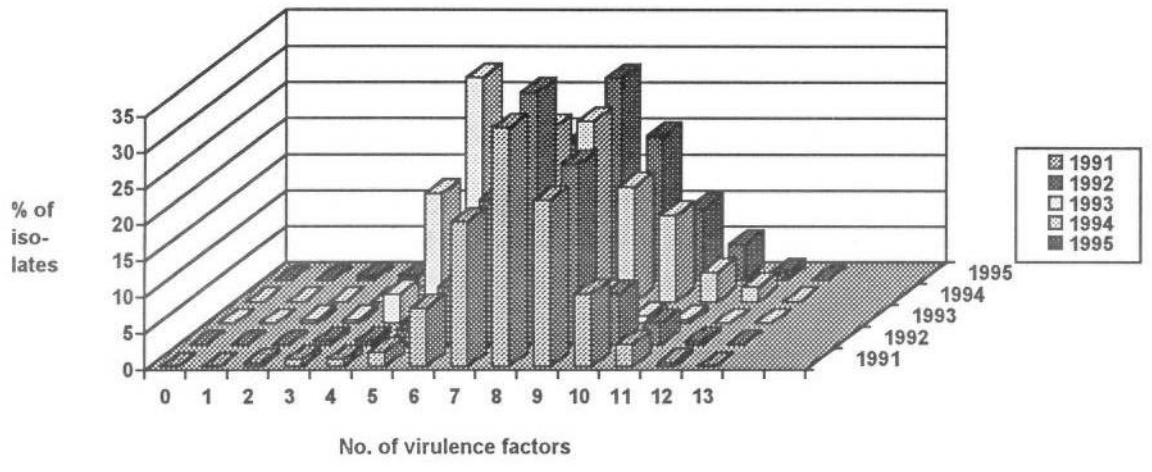
There continues to be an increase in the complexity of isolates, as exemplified in Fig. 1, with a definite trend over recent years towards pathotypes carrying an increasing number of virulence factors. However, the trend was less marked in 1995 compared with 1994. In 1993, only 15% of isolates tested had more than 7 virulence factors, compared to 59% in 1994 and 64% in 1995.

Table 4. Number of virulences carried by isolates of barley mildew in 1995 *

No. of virulence factors	% Frequency of isolates with each number of virulences			
		Random samples of airborne spores		
	Leaf samples	March	June	October
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	2	0	0
4	<1	3	1	4
5	2	9	3	8
6	8	19	10	16
7	18	23	18	22
8	28	25	29	30
9	23	15	18	12
10	13	3	12	4
11	6	0	7	2
12	4	0	0	2
13	0	0	0	0
No. of isolates	332	97	73	50

* Includes all virulences listed in Table 2 except *Va3*.

Fig.1. Comparison of the complexity of isolates collected in 1991 to 1995



Frequencies of the most common pathotypes

The frequencies of the most common pathotypes found in the 1995 samples are shown in Table 5. Again, there is a trend towards a more complex pathogen population, with a larger number of pathotypes carrying more virulence factors being recorded albeit at lower levels.

Table 5. Frequencies of the most common barley mildew pathotypes identified in 1995, defined by *Vh, Vra, Vg, V(CP), Va6, VLa, Va12, Vk1, Va7, V(Ab), Va1, Va9* and *Va13*.

Pathotypes *			Frequency of pathotypes (%)			
				Samples of airborne spores		
			Leaf sample	March	June	October
Va6	*Va12 Vk1*	*V(Ab)*	2	1	3	0
	Va12	*Va7 V(Ab)*	5	8	3	2
	Va12 Vk1	*Va7 V(Ab)*	4	2	4	0
Va6	*Va12*	*Va7 V(Ab)*	4	1	1	0
Va6	*Va12 Vk1*	*Va7 V(Ab)*	3	2	1	4
Va6	*Va12*	*Va7 V(Ab) Va1*	5	0	1	0
	Va12 Vk1	*Va7 V(Ab) Va1*	2	0	0	4
Va6	*Va12 Vk1*	*Va7 V(Ab) Va1*	3	0	3	0
Va6 V(La)	*Va12 Vk1*	*Va7 V(Ab) Va1*	2	0	3	0
	Vk1	*Va7 V(Ab) Va13*	2	2	3	2
	Va12 Vk1	*Va7 V(Ab) Va13*	2	3	1	0
Va6	*Va12 Vk1*	*Va7 V(Ab) Va13*	2	1	1	0
Total number of pathotypes			173	75	61	41
Total number of isolates			332	97	73	50

* All pathotypes also carry *Vh, Vra, Vg* and *V(CP)*.

Resistance factors in new cultivars

The resistance genes in cultivars included in the Barley Mildew Variety Diversification Scheme and the UK Recommended List candidates tested in 1995 are given in Table 6. No new resistances or combinations were identified, although some resistance combinations not found in 1994 were recorded. It is possible that some *mlo* cultivars also carry specific resistance factor(s).

The Recommended List candidates Brahms and Amber were included in the differential set of cultivars used to test the 1995 isolates. 16 isolates were virulent on Amber and 36 on Brahms, including 8 virulent on both Amber and Brahms (Table 7).

All 44 isolates possess *Va13* and most are complex isolates with 7 or more virulence factors. It is possible that both these cultivars carry *Mla13* but with additional resistance, the latter being different in the two cultivars. However, the published parentage of these cultivars does not include cultivars with known *Mla13* resistance.

Table 6. Specific resistance genes of barley cultivars.

None (BMR0)		*Mla13* (BMR10)		*Ml(Ab),Mla1* (BMR6c,7)	
Halcyon	(W)	Camargue	(S)	Brewster	(S)
Hanna	(W)	Pipkin	(W)	Chad	(S)
				Cork	(S)
Mlra (BMR1b)		*Mlra, Mla6* (BMR1b,3)		Delibes	(S)
Intro	(W)	Gaelic	(W)		
Linnet	(W)			*Ml(La),Mla1* (BMR4,7)	
Pastoral	(W)	*Mlra, Mlg, Ml(CP), Mla6*		Cooper	(S)
Sprite	(W)	(BMR1b,2,3)			
Muscat	(W)	Epic	(W)	*Ml(Ab),Mla9* (BMR6c,8)	
Tokyo	(W)			Nomad	(S)
		Mlh,Mlra,Mlg,Ml(CP),Mla6			
Mlh,Mlra (BMR 1a,1b)		(BMR1a,1b,2,3)		*mlo* (BMR9)	
Angora	(W)	Sunrise	(W)	Alexis	(S)
Melanie	(W)	Gleam	(W)	Chariot	(S)
		Mlh,Mlg,Ml(CP),Mla12		Dandy	(S)
Mlra, Mlg (BMR1b,2)		(BMR1,2,5)		Derkado	(S)
Fanfare	(W)	Puffin	(W)	Hart	(S)
Mlra (Mlg, Ml(CP) ?)		*Mlg,Ml(CP),Ml(Ab)*(BMR2,6c)		*mlo?* (BMR9?)	
(BMR1b (2a,2b ?)		Fighter	(W)	Chieftain	(S)
Regina	(W)			Pitcher	(S)
		Mla12,Ml(Ab) (BMR5,6c)		Tankard	(S)
Mlh,Mlra,Mlg,Ml(CP)		Optic	(S)	Trinity	(S)
(BMR1a,1b,2)					
Prelude	(W))	*Mlg,Ml(CP),Mla12,Ml(Ab)*		Uncertain	
		(BMR2,5,6c)		Amber	(S)
Mla9 (BMR8)		Prisma	(S)	Brahms	(S)
Manitou	(W)			Riviera	(S)
		Ml(La),Mla13 (BMR4,10)			
Mlg,Ml(CP),Mla9 (BMR2,8)		Tyne	(S)		
Felicie	(S)				

(W) winter cultivar, (S) spring cultivar

Table 7. Relative frequency of virulence factors carried by isolates virulent on Amber and Brahms.

Virulence *	Amber vir.	Vir. on Amber & Brahms	Brahms vir.
Va6	25	13	21
V(La)	100	63	18
Va12	75	63	61
Vk1	75	88	89
Va7	75	88	68
V(Ab)	25	75	93
Va1	63	13	4
Va9	50	38	43
Va13	100	100	100
No. of isols.	8	8	28

* all the isolates also carry *Vra*, *Vg* and *V(CP)* and most carry *Vh*

Fungicide Sensitivity Tests

69 isolates were selected at random from those collected in 1995 to test for sensitivity to **fenpropimorph**. The isolates were tested in three batches, with the same seven control isolates included in each batch. These control isolates were the same as those used in previous years, together with the two most insensitive isolates from 1994. The concentrations of fenpropimorph used were different from those of previous years and results from recent years cannot be directly compared. The results were expressed as ED50 values, although it was not possible to calculate these for the more sensitive isolates (Table 8).

Table 8 shows the sensitivity of the 1995 isolates, compared to the control isolates. In all tests the 1995 isolates were less sensitive than the sensitive controls. In tests 1 and 2 the means of the 23 test isolates from 1995 were lower than the means of the insensitive controls, although in test 3 the 1995 isolates were similar to the control isolates.

There appears to have been little change in sensitivity to fenpropimorph in the mildew population. However, as in 1994, although the majority of the isolates were no more insensitive than the insensitive controls, a few isolates did exhibit reduced sensitivity.

Table 8. The relative sensitivity of isolates collected in 1995 compared with the control isolates.

Source of isolates	No. of isolates	ED 50	Growth as % of growth on untreated leaves Rate of fenpropimorph (mg/l) 4	16	64	128	256
Test 1							
Sens. controls	3	-	0	0	0	0	0
Insens. controls	4	55.0	66	48	53	13	2
Roof, June	12	42.0	36	27	29	9	1
Bridgets, Hants	11	23.1	34	17	18	1	0
Test 2							
Sens. controls	3	-	30	1	0	0	0
Insens. controls	4	31.0	102	84	34	5	6
Roof, October	12	49.4*	91	44	3	3	3
Cambridge	11	25.4*	67	40	4	1	<1
Test 3							
Sens. controls	3	-	75	51	0	0	0
Insens. controls	4	60.1	94	83	69	18	3
Rothwell, Lincs.	11	75.8	89	86	48	20	1
Cambridge	12	79.5	99	86	39	21	6

* mean of 2 isolates only, remainder of isolates too sensitive to produce ED50 values

DISCUSSION

Virulences corresponding to all widely used specific resistances were recorded at high frequencies. Other virulence factors were found less frequently, generally corresponding to the occurrence of less widely used resistance genes. *Va3* was recorded at very low frequency: there is no selection for this in current UK cultivars. Isolates were obtained from *mlo* cultivars but lacked virulence in all tests. However, increasing dependence on *mlo* resistance demands close monitoring of this situation.

There was little change in the overall pattern of virulence compared with 1994 and the situation continues to be relatively stable, small frequency changes simply reflecting varying proportions of cultivars in trials and commercial use. There continues to be a trend towards increased complexity of isolates, with more pathotypes carrying more virulence factors but recorded at low frequencies.

Tests with the newer cultivars Amber and Brahms suggested that they may each carry *Mla13* plus different additional resistance. Further work is required to elucidate this situation.

There was little evidence of a shift towards insensitivity to fenpropimorph in the mildew isolates tested, although some isolates showed reduced sensitivity.

REFERENCES

Boesen, B., Hovmoller, M.S. and Jorgensen, J.H. (1994). Designations of barley and wheat powdery mildew resistance and virulence in Europe. *Proceedings of the 3rd Cereal Mildew Workshop, Zurich*, 1994, pp 48-56.

Mitchell, A.G. and Slater, S.E. (1991). Mildew of barley. *U.K. Cereal Pathogen Virulence Survey 1990 Annual Report*, pp 26-32.

Mitchell, A.G. and Slater, S.E. (1992). Mildew of barley. *U.K. Cereal Pathogen Virulence Survey 1991 Annual Report*, pp 24-31.

Mitchell, A.G. and Slater, S.E. (1993). Mildew of barley. *U.K. Cereal Pathogen Virulence Survey 1992 Annual Report*, pp 26-31.

Mitchell, A.G. and Slater, S.E. (1994). Mildew of barley. *U.K. Cereal Pathogen Virulence Survey 1993 Annual Report*, pp 38-44.

Mitchell, A.G. and Slater, S.E. (1995). Mildew of barley. *U.K. Cereal Pathogen Virulence Survey 1994 Annual Report*, pp 36-44.

Moseman, J.G., Macer, R.C.F. and Greeley, L.W. (1965). Genetic studies with cultures of *Erysiphe graminis* f.sp. *hordei* virulent on *Hordeum spontaneum*. *Transactions of the British Mycological Society* **48**, 479-489.

MILDEW OF BARLEY IN NORTHERN IRELAND

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The frequency of *Va1* (BMV 7) was identical to that in the previous year although Chad carrying the corresponding resistance gene still occupies a large crop area. Several single and multiple virulences declined, notably *Va6* (BMV 3), *Va6, VLa* (BMV 3 + 4) and *Va13* (BMV 10). The frequency of *VLa, Va13* (BMV 4 + 10) remained low and there was no significant increase in numbers of pustules on Atem. There was little difference in the level of resistance of mildew isolates to triazole seed-treatment.

Thirty-six isolates were obtained during the year using Golden Promise trap plants. The cultivars of the crops from which they came are indicated in Table 1. The cultivars used for testing virulences of isolates are shown in Table 3, while the most commonly sown cultivars in N. Ireland in the previous season, 1994/95, are shown in Table 2. Spring cultivars carrying the *mlo* gene account for 73% of the area sown.

Table 1. Sources of mildew isolates tested in 1995

Resistance gene(s)	Isolate source	No. isolates
none	Halcyon	4
Mlra	Pastoral	8
Mla9	Manitou	1
mlo	Alexis	2
mlo	Chariot	4
mlo	Dandy	2
mlo	Derkado	2
Mlra, Mla6	Gaelic	2
Ml(Ab), Mla1	Chad	7
Mlg, Ml(CP), Ml(Ab)	Fighter	2
Mlg, Mlh, Ml(CP)	Puffin	2

Table 2. Percentage use of barley cultivars in N. Ireland (1994/95)

Spring cultivars (resistance genes)	%	Winter cultivars (resistance genes)	%
Dandy (*mlo*)	34	Pastoral (*Mlra*)	41
Chariot (*mlo*)	33	Fighter (*Mlg, Ml(CP), Ml(Ab)*)	38
Chad (*Ml(Ab), Mla1*)	17	Bambi (?)	16
Hart (*mlo*)	6	Kira (*Mlra, Mlg, Ml(CP), Mla6*)	5
Felicie (*Mlg, Ml(CP), Mla9*)	4		
Tyne (*Ml(La), Mla13*)	3		

As in the previous year (Mercer, 1995), both resistance gene designations and resistance group codes are used (Table 3). The frequencies (Table 4) of the single major genes *VLa* (BMV 4) and *Va12* (BMV 5) are similar to those of the previous season. The frequency of *Va1* (BMV 7) was identical with that in 1994, in spite of the fact that Chad still continues to occupy a fairly large percentage of the spring barley area. Indeed, apart from a large increase in 1993, the levels of *Va1* have remained almost static. The frequency of *Va9* (BMV 8) increased after a considerable period of stability, although the area of Manitou, the only cultivar carrying the *Mla9* resistance gene was negligible. *Va13* (BMV 10) was present at only half the level of the previous season, possibly reflecting the reduction in popularity of Tyne. However, values for this particular virulence have been fairly variable over the years. Frequencies for combined virulences were generally within the range of variation noted in previous years with the exception of *Va6* (BMV group 3) and *Va6, VLa* (BMV 3 + 4) which both decreased sharply. The frequency of *VLa*, Va13 (BMV 4 + 10) showed no signs of an upward swing and although there was a very low frequency on the differential cultivar Atem (*MlLa, mlo*; BMR 4 + 9) it is not thought that this is significant in spite of the large area of crops carrying cultivars with the *mlo* gene and an exceptionally warm, dry summer which tends to encourage pustules to appear on such cultivars.

Table 3. Test cultivars for the detection of virulence groups.

Cultivar	Resistance gene	BMR group
Golden Promise	none	0
Zephyr	*Mlg, Ml(CP)*	2
Midas	*Mla6*	3
Goldspear	*Mla6, MlLa*	3 + 4
Varunda	*MlLa*	4
Egmont	*MlLa, Mla12*	4 + 5
Dram	*MlLa, Mlk*	4 + 6a
Klaxon	*MlLa, Mlk, Mla7*	4 + 6a + 6b
Atem	*MlLa, mlo*	4 + 9
Tyne	*MlLa, Mla13*	4 + 10
Hassan	*Mla12*	5
Keg	*Mlk, Mla7*	6a + 6b
Triumph	*Mla7, Ml(Ab)*	6b + 6c
Delta	*Mla1*	7
Leith	*Mla9*	8
Digger	*Mla13*	10

The final year of tests with Baytan seed treatment showed little difference with results from the previous year (Fig. 1). Apart from a large increase in 1989, the incidence of resistance by mildew has been relatively stable, but considerably above levels for mildews collected in the 1970s when triazole fungicides were not in use (Mercer, 1995).

REFERENCE

Mercer, P. (1995). Mildew of barley in Northern Ireland. *U.K. Cereal Pathogen Virulence Survey 1994 Annual Report*, 45-47

Table 4. Frequencies of virulence alleles from isolates collected from barley crops from 1990 -1995.

Virulence gene	**BMV group**	**Frequency of virulence alleles (%)**					
		1990	1991	1992	1993	1994	1995
Vg, V(CP)	2	43	64	39	43	77	50
Va6	3	41	54	36	47	56	26
VLa	4	27	57	25	47	42	44
Va12	5	46	54	31	67	74	61
Vk, Va7	6a + 6b	48	57	31	37	38	28
Va7, V(Ab)	6b + 6c	33	71	36	47	59	38
Va1	7	20	14	14	40	22	22
Va9	8	27	30	28	30	29	46
Va6, VLa	3 + 4	67	39	36	30	50	22
VLa, Va12	4 + 5	27	50	47	30	53	31
VLa, Vk	4 + 6a	50	50	44	30	24	33
VLa, Vk, Va7	4 + 6a + 6b	59	41	44	27	38	22
corresponding to *MlLa, mlo*	4 + 9	0	0	0	0	0	3
VLa, Va13	4 + 10	n.a.	n.a.	3	0	11	6
Va13	10	14	46	25	27	37	19

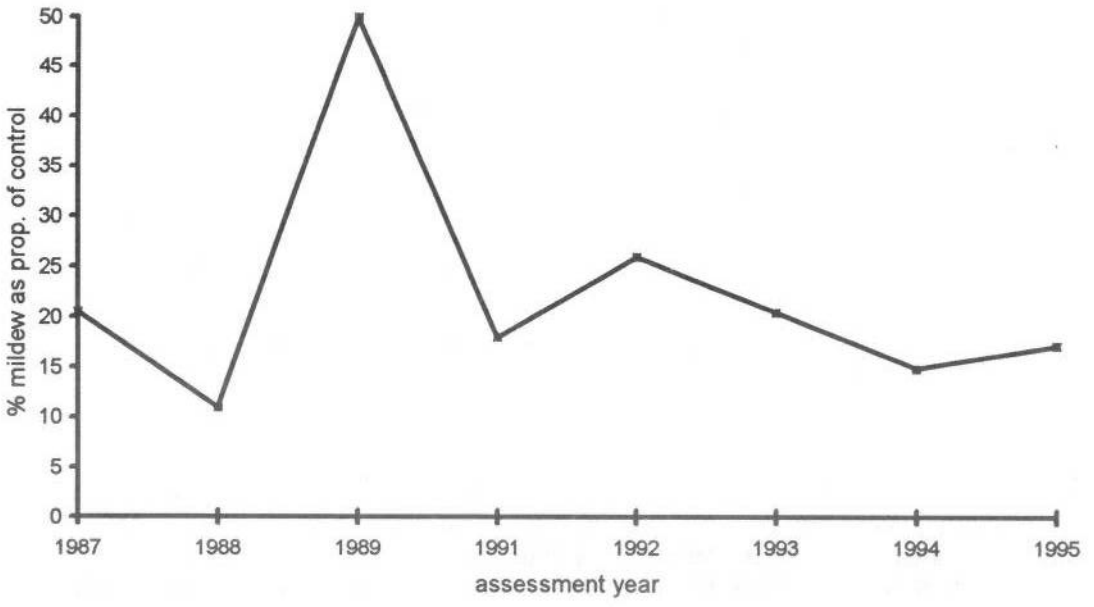

Fig. 1. Percentage of colonies of mildew growing on Baytan-treated seedlings (full recommended rate) as a proportion of those on untreated seedlings.

THE EFFECT OF THE *mlo* MILDEW RESISTANCE GENE ON RHYNCHOSPORIUM OF SPRING BARLEY

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Many spring barley varieties with mildew resistance conferred by the *mlo* gene (BMR 9) are susceptible to *Rhynchosporium secalis*. Analysis of progeny of a cross between barley varieties indicated that this increased susceptibility to *Rhynchosporium* is not caused by the *mlo* mildew resistance gene itself. In fact, there was a tendency for lines with *mlo* to be somewhat more resistant to *Rhynchosporium*. The susceptibility to *Rhynchosporium* of many spring barleys indicates that increased attention may need to be given to *Rhynchosporium* resistance in breeding and testing varieties.

INTRODUCTION

mlo (BMR 9) is now the principal source of powdery mildew resistance in spring barley in the UK. Concern was expressed at the 1995 meeting of the UKCPVS General Committee that the *mlo* mildew resistance gene might increase the susceptibility of barley varieties to *Rhynchosporium secalis*. There were two grounds for concern. One was that the general level of *Rhynchosporium* resistance in spring barley varieties has fallen in recent years, coinciding with the increased use of *mlo*. More specifically, almost all of the most *Rhynchosporium* susceptible varieties on the Recommended List have *mlo* mildew resistance (Clarkson & Slater, this report). In the 1996 RL, for example, the *mlo* varieties Chariot, Derkado and Alexis have *Rhynchosporium* ratings of 3, 3 and 4 respectively, while Tankard, which probably has *mlo*, has a rating of 3. Some *mlo* varieties, however, such as Dandy and Hart on the current RL, have better *Rhynchosporium* resistance.

Twenty-five different mildew resistance alleles of the *Mlo* gene are known, all of which are recessive. *mlo1* to *mlo10* and *mlo12* to *mlo25* were produced by mutagenesis (Jørgensen, 1994). However, almost all barley varieties with *mlo* mildew resistance have the allele *mlo11*, which, uniquely, was discovered in an Ethiopian landrace. *mlo11* varieties include Apex, Atem and Salome and their descendants, including Chariot, Dandy, Derkado, Hart and Tankard. The only important exception is Alexis, which has *mlo9* (Jørgensen, 1992).

The possibility that the *mlo* gene itself might increase susceptibility to *Rhynchosporium* was investigated. Levels of disease caused by *Rhynchosporium* were studied in progeny of a cross between two barley varieties, one with the *mlo10* mildew resistance allele and one with the mildew susceptibility allele, Mlo^{+}.

MATERIALS AND METHODS

Plant material used was kindly provided by Dr J. H. Jørgensen, Risø National Laboratory, Denmark, and multiplied at the John Innes Centre. The *mlo* (mildew resistant) parent of the

cross was SR7, which has the *mlo10* allele, produced by mutagenesis of the variety Foma. The Mlo^+ (mildew susceptible) parent was Carlsberg II. Doubled haploid (DH) lines were produced from F_1 progeny of the cross SR7 × Carlsberg II; each DH line is fully homozygous at all loci. 36 *mlo10* and 30 Mlo^+ DH lines were used (Kjær *et al.*, 1990).

Tests of *Rhynchosporium* susceptibility were done on seedlings and adult plants in the glasshouse and on adult plants in the field, as described by Jones *et al.* (this report). *Rhynchosporium* infection was scored on a 0-10 scale for seedlings, and as percentage leaf area infected (% LAI) for adult plants. Isolates RS-93-33G, RS-93-1A and RS-93-52J were used for glasshouse tests.

RESULTS

Seedling tests

Tests were carried out on all 66 DH lines, SR7, Carlsberg II and Foma. Two clumps of four plants of each line were infected with each of the three isolates. A single score was given to each clump.

Mlo^+ lines were more heavily diseased than *mlo10* lines. The mean *Rhynchosporium* score, pooled over isolates, was 8.0 for the Mlo^+ lines and 5.0 for the *mlo10* lines; the difference was highly significant ($P < 0.1\%$). There was also significant variation in the level of disease on lines with the same *Mlo* allele. Mlo^+ and *mlo* lines differed in their relative susceptibility to the three isolates, the difference between mean scores on Mlo^+ lines and on *mlo10* lines being less for isolate RS-93-33G than for the other two isolates.

Adult plant glasshouse tests

Nine *mlo10* and nine Mlo^+ DH lines, SR7 and Carlsberg II were tested as adult plants in the glasshouse. Two plants of each line were infected with each of the three isolates.

As in the seedling tests, Mlo^+ lines were more heavily diseased than *mlo10* lines, with mean %LAI across isolates of 44.8% and 26.2% respectively ($P < 0.1\%$). Again, there was significant variation between different lines with each of the two alleles of *Mlo*. There was also variation between different lines in their relative susceptibility to the three isolates, responses to RS-93-1A being particularly variable. In contrast to the seedling tests, the relative amounts of disease caused by the three isolates did not differ significantly, on average, between the Mlo^+ and *mlo10* lines.

Adult plant field trials

All 66 DH lines and the three parents were grown in a field trial and exposed to natural infection by *Rhynchosporium*. There were four replicates of each line. Once again, Mlo^+ lines were, on average, more heavily infected (13.5% LAI) than those with *mlo10* (5.7% LAI; $P < 0.1\%$), while there was significant variation between lines with the same *Mlo* allele.

Twenty-five spring barley varieties, including all of those on the current RL, were also included in the field trial. There were two replicates of each variety. Eleven varieties were either known to have *mlo* mildew resistance (either *mlo9* or *mlo11*) or were suspected to have it, because

they were very resistant to mildew, with an RL mildew rating of 8 or 9, and had at least one parent which was known to have *mlo*. The remaining 14 lines were presumed to have the Mlo^+ (mildew susceptibility) allele.

By contrast with the DH material, Mlo^+ varieties were, on average, somewhat less susceptible to *Rhynchosporium* than were the *mlo* varieties ($P < 0.1\%$). Mean %LAI were 32.2% for the Mlo^+ varieties and 40.3% for the *mlo* varieties. As with the DH lines, there was significant variation between varieties with the same *Mlo* allele.

DISCUSSION

These results indicate that the presence of the *mlo10* mildew resistance gene in the variety SR7 does not reduce resistance to *Rhynchosporium*. On the contrary, in all three tests, lines with *mlo10* were less diseased by *Rhynchosporium* than were those with the mildew susceptibility allele Mlo^+. Whether the increased resistance to *Rhynchosporium* is a direct effect of the *mlo10* allele, or an effect of a gene linked to *mlo10*, cannot be determined without further genetic analysis.

Nevertheless, many of the spring barley varieties with *mlo* mildew resistance on the current Recommended List are susceptible to *Rhynchosporium*. Indeed, field trials indicated that *mlo* varieties are slightly more susceptible to *Rhynchosporium* than are those without *mlo* (i.e. Mlo^+ varieties). There are two possible explanations for this. Firstly, our results do not exclude the possibility that the *mlo9* or *mlo11* genes, which are present in UK spring barley varieties, cause reduced resistance to *Rhynchosporium*, although the *mlo10* allele in SR7 evidently does not.

The second explanation, which is perhaps more likely, is that breeders and recommending authorities have given insufficient attention to *Rhynchosporium* resistance, so that the general level of resistance in spring barley has declined. The association of susceptibility to *Rhynchosporium* with *mlo* mildew resistance would therefore be a concidence, but one which indicates the need to maintain efforts to control the full range of diseases on barley.

ACKNOWLEDGEMENTS

We thank Helms Jørgensen for kindly providing the original plant material. The research was supported by MAFF and HGCA.

REFERENCES

Jørgensen JH, 1992. Discovery, characterization and exploitation of Mlo powdery mildew resistance in barley. *Euphytica* 63: 141-152

Jørgensen JH, 1994. Genetics of powdery mildew resistance in barley. *Critical Reviews in Plant Sciences* 13: 97-119

Kjær B, Jensen HP, Jensen J, Jørgensen JH, 1990. Associations between three *ml-o* powdery mildew resistance genes and agronomic traits in barley. *Euphytica* 46: 185-193

YELLOW RUST OF BARLEY

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Three samples from the winter barley cultivars Muscat, Tempo and Tokyo were received in 1995. Each possessed the virulence BYV 1,2.

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

Seedling test with 1995 isolates

Three samples from the winter barley cultivars Muscat, Tempo and Tokyo were received from Cockle Park Experimental Farm, Northumberland in 1995.

The samples were tested in a seedling test using the methods described by Priestley, Bayles and Thomas (1984).

RESULTS

Virulence frequencies for 1980-1995 are shown in Table 2.

Table 2 Virulence factor frequency (%)

	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95
BYV 1	100	100	100	100	100	-	-	100	-	100	100	100	100	100	100	100
BYV 2	54	81	96	87	100	-	-	100	-	100	0	100	100	100	100	100
BYV 3 †	-	-	-	17	86	-	-	22	-	75	0	0	0	0	100	0
Number of isolates	56	52	25	30	7	0	0	9	0	4	1	1	2	1	1	3

† Not included in tests before 1983.

The 1995 isolates were virulent on the BYV 1 differentials Astrix and Atem and the BYV 2 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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Seedling tests identified 6 different virulence combinations. The resistance of Cebada Capa (BBR-7) remains effective in the UK. Glasshouse tests of adult plants identified several spring barleys as carrying resistance effective only at later growth stages.

GLASSHOUSE SEEDLING TESTS WITH 1995 ISOLATES

The ninety-one barley brown rust samples received in 1995 were collected from a range of winter barley cultivars. Of these, forty-nine were sent from the CSL/ADAS Cereal Disease Survey. The geographic origins of the samples are given in Table 1.

Table 1. Geographical origin of 1995 barley brown rust samples

Location (NIAB region)	Number of samples
Central	56
South East	15
North East	10
South West	9
North West	1

Isolates of *Puccinia hordei* Otth. were cultured from forty-nine of the samples and tested on the standard set of ten differential cultivars (Table 2).

Results

The virulence combinations identified in the 49 isolates and their octal designations are given in Table 3.

Half of the isolates carried virulence to the differential cv. Ribari (BBR-3) although this resistance is seldom deployed in commercial varieties in the UK. The resistance of cv. Cebada Capa (BBR-7) remains effective against the UK pathogen population.

All virulence combinations (races) had been previously detected with the widely virulent races octal 1673 and 1677 predominating.

Table 2. Barley genotypes used to identify virulence factors in *Puccinia hordei* and their ranking for octal notation

Cultivar	BBR Factor	Gene symbol	Ranking for octal notation
Sudan	1	Pa	1
Peruvian	2	Pa_2	2
Ribari	3	Pa_3	3
Gold	4	Pa_4	4
Quinn	5	$Pa_2 + Pa_5$	5
Bolivia	6	$Pa_2 + Pa_6$	6
Cebada Capa	7	Pa_7	7
Egypt 4	8	Pa_8	8
C.I.1243	9	Pa_9	9
Triumph	10	Pa_{10}	10

Table 3. Races identified from 1995 isolates

Number of isolates	Octal designation	BBV factors
18	1673	1,2,4,5,6,8,9,10
17	1677	1,2,3,4,5,6,8,9,10
7	1657	1,2,3,4,6,8,9,10
5	1653	1,2,4,6,8,9,10
1	673	1,2,4,5,6,8,9
1	677	1,2,3,4,5,6,8,9

GLASSHOUSE ADULT PLANT TESTS

Adult Plant Tests:

Spring and winter barleys were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with one of each of the following isolates:

Race octal	BBV
657	1,2,3,4,6,8,9
1677	1,2,3,4,5,6,8,9,10
11	1,4

The plants were inoculated by spraying with a spore suspension. They were placed in

dew chambers for 16 h at 15°C post-inoculation and then incubated in the glasshouse at approximately 15°C for 14 days. Assessments were made of the percentage area of the flag leaf infected and of infection type.

Seedling Tests:

Seedlings of the cultivars, grown to the second leaf stage, were inoculated with the same isolates and incubated under the same conditions as the adult plants. Seedling x isolate interactions were classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4).

Results

These are given in Table 4. The cultivars, which expressed a range of responses to the isolates, are grouped within the table on the basis of similarities in their adult plant reactions. Infection levels were generally low on those cultivars inoculated with race octal 11.

Cultivars susceptible as seedlings and adult plants to all races included Gaelic, Halcyon, Target, Intro, Pitcher, Nomad, Dandy and Muscat. Within this group (7) there were quantitative differences with cvs Gaelic, Halcyon, Target and Intro showing high levels of Type II resistance (Clifford, 1985), commonly referred to as slow rusting or partial resistance.

A group (6) of three cultivars, namely Cork, Alexis and Camargue, also showed high levels of Type II resistance as adult plants but were separated from Group 7 cultivars by having a resistant seedling reaction to race octal 11.

Most of the cultivars within Groups 1-5 were resistant to the simple race octal 11. Group 2 cultivars expressed resistance to race octal 657 which lacks virulence factors 5 and 10, but susceptible, albeit at generally low levels, to race octal 1677. Conversely within Group 4 cvs Felicie, Tankard and Chieftain were susceptible to race octal 657 but displayed a mixed, mainly resistant response to race octal 1677 which carries additional virulences.

Cultivars Derkado, Trinity and Brewster (Group 1) were resistant to all the isolates. This resistance was not expressed in the seedling tests to the two more complex isolates. Similarly cultivars within Group 2 appear to carry adult plant resistance although it is only effective against isolate octal 657 in these tests.

REFERENCES

Clifford, B.C. (1985). Barley Leaf Rust. In: The Cereal Rusts Vol.2. Eds A.P. Roelfs and W.R. Bushnell, pp.173-205.

Table 4. *Percent infection of adult plants and seedling reactions of barley cultivars to specific isolates of *Puccinia hordei* under glasshouse conditions

Cultivar / Isolate	Group	Octal 657 (BBV-1,2,3,4,6,8,9)		Octal 1677 (BBV-1,2,3,4,5,6,8,9,10)		Octal 11 (BBV-1,4)	
Derkado		1 R	(S)	5 R	(S)	5 R	(MS)
Trinity	1	13 MR	(S)	9 MR	(S)	2 MR	(R)
Brewster		13 R	(S)	5 MR	(MS)	3 MR	(R)
Cooper		8 R	(S)	1	(MR)	2 MR	(R)
Hart		2 R	(S)	5	(S)	Trace	(S)
Optic		9 R	(S)	2	(S)	6 R	(MS)
Chariot		3 R	(S)	4 MS	(S)	3 R	(S)
Chad	2	12 R	(S)	9	(S)	3 MR	(R)
Heron		15 MR	(S)	6 MS	(MR)	3 R	(R)
Tyne		13 MR	(S)	3 MS	(S)	5 MR	(R)
Delibes		16 R	(S)	4 MS	(MR)	0.5 MS	(R)
Prisma		29 R	(S)	7	(S)	2 MS	(S)
Vada	3	15 MR	(-)	10 MR	(-)	6 MS	(-)
Felicie		11	(S)	10 MR	(S)	1 MR	(MS)
Tankard	4	14	(MS)	9 MR	(MS)	10 MR	(R)
Chieftain		15 MS	(S)	10 MR	(S)	5 R	(R)
Mentor		5	(S)	5	(S)	Trace R	(S)
Brahms		8 MS	(S)	4	(MR)	2 R	(MR)
Riviera	5	9	(S)	10 MS	(S)	7 MR	(S)
Corsair		10	(-)	9	(-)	10 MR	(-)
Cork	6	1	(R)	9 MS	(S)	3 MS	(R)
Alexis		3	(S)	7	(S)	Trace	(MR)
Camargue		4	(S)	8	(S)	3	(MR)
Gaelic (W)	7	4	(S)	1	(S)	4	(S)
Halcyon (W)		4	(S)	6	(S)	0.5	(MS)
Target (W)		5	(-)	8	(-)	0.5	(-)
Intro (W)		7	(S)	4 MS	(S)	3 MS	(S)
Pitcher		15 MS	(S)	13 MS	(S)	5 MS	(S)
Nomad		15	(S)	16	(S)	2	(S)
Dandy		23	(S)	15	(S)	4 MS	(S)
Muscat (W)		25	(-)	11	(-)	2	(-)

*Percentage - mean of 2 replicates

R = resistant MR = mixed resistant S = susceptible

MS = mixed susceptible W = winter barley ( ) seedling reaction

Cvs in **bold** text are Fully Recommended

RHYNCHOSPORIUM OF BARLEY

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Three isolates from the 1995 survey induced infection levels sufficiently high to classify the winter cv. Digger as being susceptible. The spring cvs Brahms and Chieftain were identified as carrying the specific resistance BRR-5 present in cv. Pipkin winter barley. The majority of current spring barleys are highly susceptible. A number of winter barley cultivars carry resistance factor BRR-2.

SEEDLING TESTS WITH 1995 ISOLATES

Leaves infected with *Rhynchosporium secalis* were received from a range of 40 winter and 7 spring barley cultivars in 1995. These included 5 samples received from the CSL/ADAS Cereal Disease Survey. The geographic origins of the samples are given in Table 1.

Table 1. Geographic origin of *Rhynchosporium* samples received in 1994

Location (NIAB Region)	Number of samples
North East	16
Central	20
South-east	6
South-west	5

Twenty-three isolates were successfully tested on a set of differential cultivars, carrying resistance of relevance to UK agriculture, together with additional winter and spring barleys. Test cultivars and their resistance factors are given in Table 2.

Results

The isolates tested gave a range of previously identified virulence combinations when classified by their reactions on the standard set of differential cultivars (Table 3).

Table 2. Differential test cultivars for *Rhynchosporium secalis*

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

Table 3. Virulence factor combinations identified from the 1995 survey

No. of isolates	Differential cultivars in linear order							Race octal
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
5	0	0	0	0	1	0	0	4
1	0	0	0	1	1	0	0	14
3	1	0	0	1	1	0	0	114
2	0	0	0	0	1	1	1	7
2	0	0	0	1	1	1	1	17
2	1	0	0	1	1	1	1	117
4	0	0	1	1	1	0	0	34
1	0	1	1	0	0	0	0	64
1	0	1	1	1	1	0	0	74
1	1	1	1	1	1	0	0	174
1	0	0	0	1	0	0	0	10

1 = susceptible 0 = resistant

Virulence to cv. La Mesita (BRR-5) was detected in 7 isolates in 4 different combinations. Three of these isolates were sampled from crops of cv. Pipkin which is known to carry resistance factor BRR-5 derived from cv. La Mesita, and one from the spring barley cv. Brahms which also appears to carry the same resistance factors (see Glasshouse Tests). Three of the La Mesita virulent isolates also carry virulence to cv. Osiris, these being the only isolates identified as carrying factor BRR-6 from the 1995 samples.

Increased virulence to the spring barley cv. Digger detected in 1994 was confirmed when 3 isolates cultured from the 1995 leaf samples induced infection levels classified as being susceptible. The samples were from three spring barleys grown at a farm in East Lothian.

Frequencies of virulences (Table 4) to cvs Armelle (BRR-1) and Astrix (BRR-2) were at

a reduced level in 1995 reversing the trend of the previous three seasons. This may be a reflection of unrepresentative sampling and/or the lower number of isolates tested, as several of the currently NIAB Recommended cultivars appear to carry the resistance factors BRR-1 and BRR-2 (see Glasshouse Tests). The frequency of isolates carrying virulence to cv. Pirate (BRR-7) also decreased.

Table 4. Frequencies of individual virulences, 1988-1995

	BRV-							No. of isolates
	7	6	5	4	3	2	1	
1988	0.81	0	0	0.98	0.98	0.19	0.19	48
1989	0.54	0.08	0.23	0.92	0.92	0.62	0.62	15
1990	0.54	0.23	0.30	0.76	0.92	0.23	0.23	13
1991	0.28	0	0	0.52	0.74	0.22	0.22	50
1992	0.50	0.07	0.10	0.86	0.97	0.40	0.40	30
1993	0.57	0.07	0.12	0.94	1.00	0.68	0.68	69
1994	0.85	0.07	0.15	0.97	0.99	0.88	0.88	67
1995	0.26	0.13	0.30	0.65	0.91	0.26	0.26	23

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF *RHYNCHOSPORIUM*

Thirty winter and 29 spring barleys were grown in the glasshouse until full emergence of the flag leaf. Additional sets comprising 4 plants of each of the cultivars were sown at a later date and grown to the second leaf stage. Two replicates of each cultivar (adult plants) and a set of the seedlings were each inoculated with a spore suspension of each of the following isolates.

Isolate	BRV-	Race octal
RS-93-33G	3	4
RS-93-1A	1,2,3,4,7	117
RS-93-52J	3,5,6,7	164

Plants were inoculated by spraying with a fresh spore suspension, placed in dew chambers at 15°C for 48 h post-inoculation and then incubated in the glasshouse at approximately 15°C for 16 days. Adult plants were assessed on the percentage area of the flag leaf infected. Seedlings were assessed on a 0-9 scale (0-4: resistant; 5-9: susceptible).

Results

Seedling and adult plant test results are given in Table 5 (winters) and Table 6 (springs). Cultivars are grouped within the tables on the basis of similarities in their patterns of response to the isolates.

Seedling tests: winter barleys

Many of the winter barley cultivars (Table 5) carried race-specific resistances. Cultivar Pipkin (BRR-5) was susceptible to isolate RS-93-52J which carries the corresponding virulence factor.

The resistance of cv. Astrix (BRR-2) was effective against isolate RS-93-33G (race octal 4) and RS-93-52J (race octal 164) but was overcome by isolate RS-93-1A (race octal 117). Several other cultivars were also only susceptible to this isolate indicating that they carry resistance factor BRR-2 in common with cv. Astrix.

Cultivar Igri (BRR-4) was susceptible to isolate RS-93-33G to which it had been resistant in previous seedling tests but its responses to the other 2 isolates confirmed previous results. A group of cultivars was susceptible to all three isolates as was cv. Pirate (BRR-7) which was previously resistant to isolate RS-93-33G in the 1994 seedling tests but susceptible in adult plant glasshouse tests.

Seedling tests: spring barleys

The susceptible responses of cvs La Mesita (BRR-5) (Table 6) and Osiris (BRR-6) to race octal 164 (RS-93-52J) confirmed them as carrying BRV-5 and BRV-6 respectively. Other cultivars responding similarly to the isolates were Brahms and Chieftain.

With the exception of cv. Armelle (BRR-1), which was susceptible to the only isolate carrying BRV-1 (RS-93-1A), and cv. Digger, which was resistant to the isolates, the cultivars were susceptible.

Adult plant tests: winter barleys

Within the winter barleys, cv. Linnet was resistant to isolates RS-93-33G and RS-93-52J, suggesting that it may carry resistance factor BRR-2. Cultivar Target was also resistant to these isolates but, because it was also resistant to isolate RS-93-1A, it is grouped with cvs Fighter and Manitou. These cultivars appear to carry additional adult plant resistance.

Previous years' results have indicated that cv. Igri (BRR-4) has adult plant resistance effective against some isolates. This adult plant resistance was effective against isolate RS-93-33G which, although not originally identified as carrying virulence factor BRV-4, was virulent on cv. Igri in these seedling tests.

The differential cv. Athene (BRR-3) was resistant to race octal 4 (RS-93-33G) and race octal 164 (RS-93-52J) although in 1994 seedling and adult plant tests (Jones *et al.*, 1995) and in 1995 seedling tests it was susceptible to these isolates. These data are difficult to explain but may be due to a seed error. Likewise the responses of cv. Pirate (BRR-7) did not confirm previous results, which indicated that it carries a race-specific seedling resistance (BBR-7), confirmed by the 1995 Survey results reported here. The currently reported seedling and adult plant tests indicate that it also carries a race-specific adult plant resistance.

Adult plant tests: spring barleys

The spring barley cv. La Mesita (BRR-5) was susceptible as an adult plant to isolates not carrying the corresponding virulence (BRV-5) and to which it was resistant as a seedling but it was more heavily infected by isolate RS-93-52J (race octal 164) which does (Table 6). Cultivars Chieftain and Brahms, thought to carry either BRR-5 or BRR-6 on the basis of seedling test data, responded similarly to cv. La Mesita (BRR-5) to the isolates.

The specific overall resistance of cv. Osiris (BRR-6) was overcome by race octal 164 although infection levels were low. This isolate also induced similar disease levels on cv. Digger which has previously expressed high levels of resistance as an adult plant although it has shown infection levels of 10%-15% in seedling tests to a few isolates.

The race-specific resistance of cv. Armelle (BRR-1) was confirmed.

The majority of the currently-recommended spring barley cultivars were susceptible in these tests.

ADULT PLANT FIELD TESTS (SPRING BARLEYS)

A nursery comprising currently recommended spring barleys and additional cultivars carrying known specific resistances was grown at a site in Mylnfield, Scotland. The cultivars within the nursery became infected with naturally-occurring pathotypes.

Assessments of infection levels were made throughout the season and results are given in Table 7. Although disease levels were low, the cultivars displayed a range of quantitative responses with cultivar rankings generally confirming the NIAB Disease Rating. The resistance of cv. Digger remained effective. Cultivar La Mesita (BRR-5), which is susceptible at later growth stages to the majority of isolates including those which are not identified as carrying the corresponding virulence factor in seedling tests, was resistant in these tests.

REFERENCE

Jones, E.R.L., Clifford, B.C. and Newton, A.C. (1995). *Rhynchosporium* of barley. United Kingdom Cereal Pathogen Virulence Survey 1994 Annual Report, pp.52-60.

Table 5. †Percent infection of adult plants and seedling reactions* of winter barley cultivars to specific isolates of *Rhynchosporium secalis* in glasshouse tests

Isolate Cultivar	RS-93-33G (race octal 4) BRV-3		RS-93-1A (race octal 117) BRV-1,2,3,4,7		RS-93-52J (race octal 164) BRV-3,5,6,7	
Pipkin (BRR-5)	3	(1)	5	(0)	75	(9)
Astrix (BRR-2)	-	(0)	-	(9)	-	(0)
Intro	0	(0)	45	(9)	3	(0)
Regina	0.5	(0)	40	(9)	0	(0)
Tempo	1	(0)	65	(9)	0	(0)
Melanie	0	(0)	45	(8)	0	(0)
Angora	2	(0)	38	(8)	0	(0)
Sunrise	0	(0)	38	(7)	0	(0)
Gleam	0	(0)	8	(7)	0	(0)
Corsair	0	(0)	40	(6)	0	(0)
Halcyon	1	(0)	33	(9)	0	(0)
Hanna	8	(1)	33	(9)	3	(3)
Sprite	0	(2)	50	(8)	0	(4)
Epic	-	(0)	-	(-)	-	(4)
Linnet	5	(4)	50	(8)	5	(6)
Fighter	1	(8)	3	(2)	3	(7)
Manitou	3	(8)	1	(1)	5	(5)
Target	0.5	(4)	5	(8)	0	(5)
Igri (BRR-4)	0	(5)	45	(9)	0	(1)
Athene (BRR-3)	5	(8)	55	(9)	0	(8)
CPB7	45	(6)	60	(8)	18	(0)
Muscat	35	(7)	50	(9)	10	(5)
Gaelic	50	(5)	55	(9)	35	(7)
Puffin	13	(6)	23	(7)	8	(8)
Fanfare	-	(6)	-	(6)	-	(7)
Prelude	30	(6)	25	(6)	23	(7)
Tokyo	10	(8)	10	(7)	15	(7)
Pastoral	25	(8)	50	(8)	3	(9)
Maris Otter	-	(6)	-	(9)	-	(9)
Pirate (BRR-7)	33	(7)	6	(6)	3	(6)

† Percentage - mean of 2 replicates

* Assessment of leaf area infected on a 0-9 scale

Resistant: 0-4, Susceptible: 5-9

( ) seedling reaction

Table 6. †Percent infection of adult plants and seedling reactions* of spring cultivars to specific isolates of *Rhynchosporium secalis* in the glasshouse

Isolate Cultivar	RS-93-33G (race octal 4) BRV-3		RS-93-1A (race octal 117) BRV-1,2,3,4,7		RS-93-52J (race octal 164) BRV-3,5,6,7	
La Mesita (BRR-5)	† 40	* (0)	55	(0)	90	(7)
Osiris (BRR-6)	5	(0)	0	(0)	13	(8)
Chieftain	10	(0)	20	(0)	75	(9)
Brahms	28	(3)	30	(1)	80	(9)
Armelle (BRR-1)	0	(0)	65	(9)	0	(0)
Digger	0.3	(2)	2	(0)	10	(2)
Amber	20	(7)	25	(8)	70	(4)
Brewster	50	(8)	35	(7)	60	(3)
Chariot	60	(9)	60	(9)	90	(8)
Optic	65	(9)	80	(9)	80	(9)
Riviera	60	(9)	70	(9)	80	(9)
Cooper	50	(9)	53	(9)	65	(9)
Delibes	48	(9)	65	(8)	75	(9)
Camargue	65	(9)	60	(9)	80	(9)
Prisma	55	(9)	65	(9)	85	(9)
Trinity	55	(9)	65	(9)	75	(7)
Mentor	60	(9)	60	(9)	85	(8)
Hart	75	(9)	70	(9)	80	(8)
Derkado	50	(9)	60	(9)	80	(9)
Dandy	50	(9)	14	(8)	50	(7)
Cork	70	(9)	65	(8)	80	(7)
Tyne	28	(9)	5	(8)	60	(8)
Pitcher	50	(9)	50	(9)	48	(8)
Tankard	48	(9)	65	(9)	75	(9)
Heron	45	(9)	50	(9)	80	(9)
Felicie	48	(9)	70	(9)	80	(9)
Nomad	50	(9)	70	(9)	80	(9)
Alexis	55	(9)	75	(9)	90	(9)
Chad	50	(9)	60	(9)	80	(9)

† Percentage - mean of 2 replicates
* Assessment of leaf area infected on a 0-9 scale

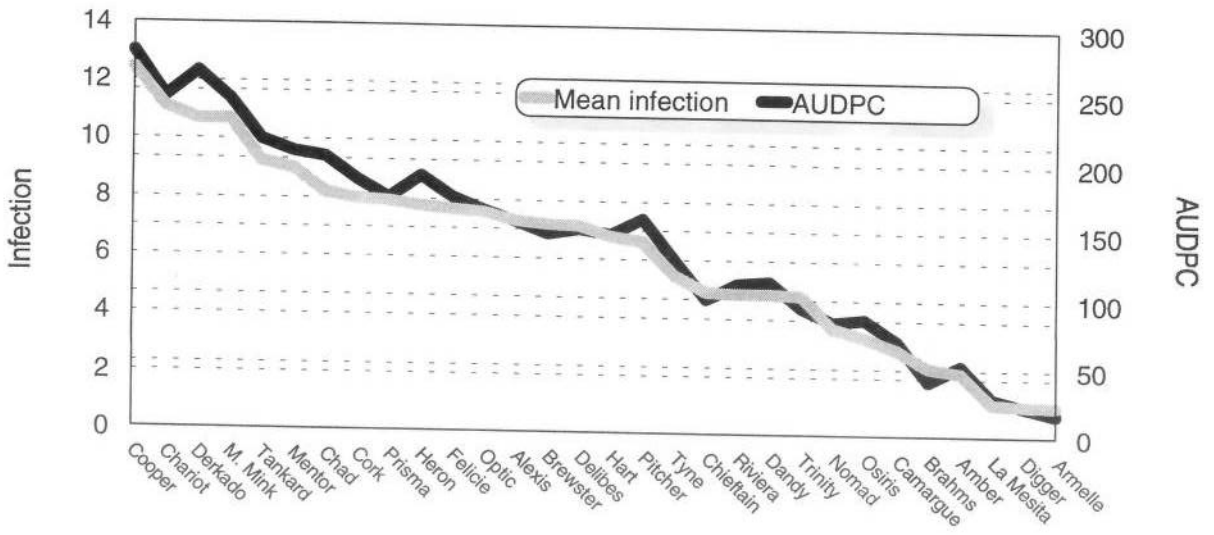
Resistant: 0-4, Susceptible: 5-9

( ) seedling reaction

Table 7. Infection of spring barley cultivars in the SCRI *Rhynchosporium* nursery in 1995

Cultivar (+ NIAB rating)		Mean*	AUDPC#
Cooper	(5)	12.42	278.6
Chariot	(3)	11.08	245.4
Derkado	(3)	10.67	264.4
M. Mink		10.67	243.8
Tankard	(3)	9.25	214.4
Mentor		9	205.6
Chad	(5)	8.2	201.9
Cork	(6)	8	185.3
Prisma	(7)	7.92	172.4
Heron	(5)	7.78	188.7
Felicie	(7)	7.67	173.3
Optic	(5)	7.58	163.6
Alexis	(4)	7.28	155.7
Brewster	(7)	7.17	146.8
Delibes	(7)	7.12	150.2
Hart	(6)	6.78	146.4
Pitcher		6.62	158.7
Tyne	(5)	5.47	128.6
Chieftain		4.88	99.2
Riviera	(4)	4.84	110.6
Dandy	(7)	4.83	112.7
Trinity		4.79	94.2
Nomad	(6)	3.7	83.4
Osiris		3.38	85.9
Camargue	(8)	2.98	70.5
Brahms		2.36	40.9
Amber		2.21	52.4
La Mesita		1.15	28.1
Digger		1.08	22
Armelle		1.06	16.4
SED		1.73	51.86

* = Mean of three scores # = Area under the disease progress curve (AUDPC)



NET BLOTCH OF BARLEY

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Isolates carrying a range from 1 to 9 virulence factors were identified from the 1995 net blotch samples. The resistance conferred by the differential cv. C.I.5401 was effective confirming the recommendation of its value to breeders. Glasshouse tests with specific isolates of the pathogen identified some spring barleys as being resistant to a netting isolate but susceptible to a spotting isolate.

GLASSHOUSE SEEDLING TESTS WITH 1995 ISOLATES

Forty-three samples of net blotch were received. This number includes 20 samples received from the CSL/ADAS Disease Survey. Fourteen samples were from cv. Puffin, 6 from cv. Pastoral with the remainder coming from a range of winter barley cultivars and two from spring barleys. The geographic origins of the samples are given in Table 1.

Table 1. Geographic origins of net blotch samples received in 1995.

Location NIAB region	Number of samples
North East	19
South East	11
South West	8
Central	5

Thirty-two isolates were successfully tested on a set of 13 differential cultivars together with cv. Marinka.

Results

Virulences compatible with the resistance factors in 11 of the differential cultivars were identified. Although virulence to the resistance factors in all the differential cultivars have been identified previously, the frequencies of virulence have fluctuated from season to season. Only the resistances conferred by cv. C.I.5401 and C.I.4502 were effective against all the 1995 isolates (Table 2).

The virulences identified occurred in various combinations in the different isolates. The virulence combinations which are based on the differential code numbers (Table 2) gave

a range from a single virulence factor in one isolate to combinations comprising up to nine virulence factors in others (Table 3).

Table 2. Virulence frequencies (%) corresponding to each differential cultivar (UK CPV Surveys 1990-1995).

Code Number	Cultivar	1990	1991	1992	1993	1994	1995
1	C.I.5401	0	0	0	0	0	0
2	C.I.6311	13	13	2	0	14	13
3	C.I.9820	0	0	0	0	3	6
4	C.I.739	31	31	13	0	14	38
5	C.I.1243	13	13	9	0	23	13
6	C.I.4795	13	13	4	0	6	9
7	C.I.4502	19	19	4	0	11	0
8	C.I.4979	38	38	4	0	29	44
9	Proctor	56	56	52	43	97	88
10	Code 65(W)	31	31	9	100	3	16
11	C.I.9518(W)	88	88	56	29	100	100
12	Tenn.61-119(W)	75	75	50	0	69	50
13	C.I.9214	19	19	4	0	3	9
No. of isolates tested		15	15	46	7	35	32

W = winter cv.

Table 3. Virulence combinations based on the differential code numbers identified from the 1995 samples

Virulence combination	Number of isolates	Virulence combination	Number of isolates
11	1	4,9,11,12,M	1
11,M	1	4,8,9,11,12	1
9,11	10	4,8,9,11,12,M	3
9,11,M	1	3,8,9,11,12,M	1
4,11	1	2,4,9,10,11,12,M	1
9,11,12	2	4,5,8,9,10,11,12,M	1
8,11,12	1	2,4,8,9,10,11,12,M	1
8,9,11,M	1	2,3,4,6,8,9,11,12,13	1
8,9,11,12	1	2,4,6,8,9,11,12,13,M	1
8,9,10,11	1	4,5,6,8,9,10,11,12,13,M	1

M = virulent on cv. Marinka

Cultivar Marinka was susceptible to 13 of the 1995 isolates tested. Virulence to this previously resistant cultivar was first detected, at a high frequency, in 1987. Since then

the frequency of isolates carrying this virulence has shown a general decline (Jones and Clifford, 1993), although this trend has been reversed in 1995.

GLASSHOUSE TESTS

Adult Plants:

Winter and spring barley cultivars were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated (Clifford and Jones, 1981) with a spore suspension of each of a 'netting' isolate and 'spotting' isolate. Spore suspensions were obtained by soaking barley leaves infected with the pathotypes for 24 h. These were then mixed thoroughly and the spore suspension filtered through muslin. The virulence factors carried by the isolates were:

	BNV-	Origin
Netting isolate	4,8,9,11,12	cv. Pastoral, Devon
Spotting isolate	1,4,5,9,11,13	cv. Hart, Dyfed

Following inoculation, the plants were then placed in dew chambers in the dark at 15°C for 24 h post-inoculation before returning to the glasshouse for 12 days.

Assessments were made of the area of flag leaves infected and cultivars were classified on a 0-9 scale as being resistant (0-4) or susceptible (5-9).

Seedlings:

Seedlings of the cultivars grown to the 2nd leaf stage in the glasshouse were inoculated with the isolates under identical conditions as the adult plants. Seedlings were assessed on infection levels on the second leaf and classified on the same 0-9 scale.

High levels of infection developed on the susceptible cultivars, symptoms being of a striping or netting type to the 'netting' isolate, but of a 'spotting' or 'blotching' type to the 'spotting' isolate.

Results

Winter barleys: The cultivars (Table 4) expressed a mainly susceptible response as seedlings and adult plants to both isolates although quantitative differences in infection levels were apparent. Cultivar rankings between isolates followed a similar pattern.

Although the majority of the winter barleys were susceptible as seedlings to the isolates, cvs Fighter (susceptible in adult plant tests), Epic, Intro and Halcyon were classified as resistant to the 'netting' isolate.

Spring barleys: The spring cultivars (Table 5) displayed a greater range of quantitative responses to the isolates than the winter barleys. A number of cultivars were resistant (0-4) to the 'netting' isolate although some of these were seedling susceptible, suggesting that they carry adult plant resistance effective against some isolates. Cultivar Felicie expressed high levels of resistance to the netting isolate indicating that it may carry a specific resistance effective against the virulence factors carried by the isolate.

The spotting isolate induced a susceptible response on all the cultivars except for cvs Tyne, Derkado and Trinity which were classified as resistant. Seedlings of the cultivars were also generally more susceptible to this isolate. The wider range of spring barleys susceptible to the 'spotting' isolate may be due to the different and additional virulence factors carried by the pathotype. Alternatively it may be that host:pathogen interactions are being influenced by the two forms of the pathogen used in these tests. Previous results have shown that some cultivars susceptible to the netting form are resistant to the spotting form and *vice versa* (Clifford and Jones, 1995).

REFERENCES

Clifford, B.C. and Jones, E.R.L. (1985). Net Blotch of Barley, UK Cereal Pathogen Virulence Survey 1984 Annual Report, pp.70-75.

Clifford, B.C. and Jones, Deryk (1981). Net Blotch of Barley, UK Cereal Pathogen Virulence Survey 1980 Annual Report, pp.71-77.

Table 4. Reactions of winter barley cultivars (adult plants and seedlings) to typed isolates of net blotch under glasshouse conditions.

Isolate		'Net'		'Spot'	
Cultivar (NIAB Rating)		BNV-4,8,9,11,12		BNV-1,4,5,9,11,13	
Tempo		* 9		7	
Gleam	(6)	9	(9)	7	(8)
Sunrise	(5)	9	(8)	5	(9)
Hanna	(8)	8	(7)	6	(9)
Melanie	(6)	8	(6)	7	(8)
Puffin	(5)	8	(9)	4	(9)
Angora	(6)	7	(8)	8	(9)
Prelude	(9)	7	(9)	5	(9)
Linnet	(8)	6	(6)	6	(6)
CPB7		6		6	
Manitou	(6)	6	(7)	5	(5)
Tokyo		6	(8)	4	(9)
Fighter	(8)	5	(2)	4	(7)
Pastoral	(8)	4	(6)	7	(7)
Pipkin	(9)	4	(8)	5	(9)
Spice		-	(9)	-	(9)
Sprite	(8)	-	(8)	-	(9)
Portrait		-	(8)	-	(8)
Gaelic	(8)	-	(8)	-	(8)
Falcon		-	(8)	-	(7)
Regina	(9)	-	(6)	-	(9)
Muscat	(8)	-	(6)	-	(8)
Rifle		-	(5)	-	(7)
Epic	(8)	-	(4)	-	(8)
Intro	(8)	-	(3)	-	(7)
Halcyon	(8)	-	(2)	-	(5)

* = assessments of leaf area infected on a 0-9 scale (mean of 2 plants)
Resistant: 0-4, Susceptible: 5-9
( ) seedling reaction
Cv. ( ) = NIAB rating: 1 = susceptible, 9 = resistant

Table 5. Reactions of spring barley cultivars (adult plants and seedlings) to typed isolates of net blotch under glasshouse conditions.

Isolate	'Net'		'Spot'	
Cultivar	BNV-4,7,9,11,12		BNV-1,4,5,9,11,13	
Mentor	* 9	(5)	9	(9)
Amber	8	(1)	8	(7)
Camargue	7	(8)	7	(9)
Cork	7	(7)	7	(6)
Cooper	6	(7)	7	(9)
Prisma	5	(6)	9	(9)
Heron	5	(6)	6	(9)
Brahms	5	(8)	5	(8)
Alexis	5	(7)	5	(9)
Tyne	5	(4)	4	(9)
Derkado	5	(3)	3	(6)
Delibes	4	(4)	8	(9)
Brewster	4	(5)	8	(5)
Hart	4	(4)	7	(8)
Pitcher	4	(4)	5	(8)
Optic	4	(2)	7	(5)
Dandy	3	(1)	9	(5)
Chad	3	(5)	8	(8)
Nomad	3	(6)	6	(7)
Riviera	3	(8)	6	(6)
Tankard	3	(5)	5	(7)
Chieftain	3	(4)	5	(8)
Chariot	2	(5)	7	(8)
Felicie	1	(0)	6	(6)
Trinity	1	(6)	3	(7)

* = assessments of leaf area infected on a 0-9 scale (mean of 2 plants)
Resistant: 0-4, Susceptible: 5-9
( ) seedling reaction

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

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Of 58 infected samples received in 1995, 40% contained barley yellow mosaic virus (BaYMV) and 86% barley mild mosaic virus (BaMMV). Most samples were of Puffin on which BaMMV is known to predominate and on which symptoms are often very pronounced. No new outbreaks of resistance-breaking BaYMV were reported.

INTRODUCTION

The survey, begun in 1987, aims to determine the distribution and relative frequency of the two mosaic viruses (barley mild mosaic virus: BaMMV; barley yellow mosaic virus: BaYMV) on winter barley, to detect regional or cultivar differences and to monitor the development of resistance-breaking strains. The viruses are soil-borne, being transmitted by the root infecting fungus *Polymyxa graminis*, and persist in soil for many years. A single (recessive) gene (*ym4*) confers immunity to the common isolates of both viruses in a number of European cultivars but, since 1988, resistance-breaking isolates of BaYMV ("BaYMV-2") have been detected in the UK and other parts of Europe. Several strains of BaYMV with different specific virulences have been reported in Japan. New cultivars with resistance genes from East Asian barleys are being developed for the European market and a knowledge of the variation in these viruses and of their interaction with barley genotypes is therefore likely to become increasingly important.

METHODS

Plants with symptoms were received from farmers as a result of publicity by the Arable Research Centres and NIAB and some also came via MAFF CSL Harpenden Laboratory. Leaves were tested by enzyme-linked immunosorbent assay (ELISA) for the presence of both viruses as described by Adams (1990).

RESULTS AND DISCUSSION

58 positive samples were received in 1995, slightly more than in 1994. Most samples (86%) contained BaMMV and 40% had BaYMV (Table 1). The proportion with both viruses (26%) was rather larger than in previous years. For the 33 samples of which the cultivar was known, 22 were of Puffin, on which (as for the other malting cultivars) BaMMV has been predominant in previous years. Symptoms on Puffin are also often very pronounced with chocolate-brown necrotic flecks in addition to the typical pale yellow mosaic symptoms. No new outbreaks of resistance-breaking BaYMV were reported.

Table 1. Mosaic virus samples from 1995, classified by cultivar

Cultivar	BaMMV alone	BaYMV alone	Both	Total Samples
Halcyon	1	0	1	2
Maris Otter	1	0	0	1
Pipkin	1	0	2	3
Puffin	17	1	4	22
Malting	20	1	7	28
Fighter	0	0	1	1
Manitou	0	1	0	1
Pastoral	2	0	0	2
Plaisant	0	1	0	1
Feeding	2	2	1	5
Unknown	13	5	7	25
Total	35	8	15	58

REFERENCE

ADAMS M.J. (1990). The distribution of barley yellow mosaic virus (BaYMV) and barley mild mosaic virus (BaMMV) in UK winter barley samples, 1987-1990. *Plant Pathology* **40**, 53-58.

MILDEW OF OATS

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Race 5 (OMV 1,2,3) was identified from the 14 isolates tested in 1995. Seedlings of a number of spring and winter oats were susceptible to all the isolates.

SEEDLING TESTS WITH 1995 ISOLATES

Forty-four samples of *Erysiphe graminis avenae* were received in 1995 from a wide range of winter (22) and spring (23) oat cultivars. The majority (41) of these samples came from 3 trial sites. Isolates were cultured from 14 of the leaf samples and tested on a set of differential cultivars (Table 1). No mildew isolates were cultured from a batch of winter oat cultivars sampled at a trial site in St. Clears, Dyfed, the majority of which were heavily infected with crown rust. Also included in the tests were spring and winter oats recommended for use by the NIAB, Cambridge.

Table 1. Differential cultivars used for isolate testing

OMR Group	Differential cultivar
0	Milford
1	Manod
2	Cc 4146
3	9065 Cn 6/3/74
4	Cc 6490

Table 2. Additional spring and winter oat cultivars included in tests with 1995 isolates

Winter oats	Spring oats
Aintree	Aberglen
Pendragon	Dula
Kynon	Valiant
Chamois	Melys
Gerald	Minerva
Solva	Bruno
Mirabel	Rhiannon
Image	Neon

Results

Details of the mildew samples tested are given in Table 3.

Race 5 (OMV-1,2,3) was the only race identified. This relatively complex race which has increased in frequency in recent years at the expense of the simpler races 2 (OMV-1), 3 (OMV-1,2) and 4 (OMV-1,3) was virulent on all the additional winter and spring cultivars included in the tests. It may be that some of the cultivars carry resistance which are effective to the less widely virulent races but because of the current unavailability of these 'simpler' races in the UK it is not possible to identify any such resistance(s). Resistance conferred by the differential Cc6490 (OMR-4) was effective against the 1995 isolates.

Table 3. Locations and cultivars from which viable mildew samples were received in 1995 with virulences for each sample

Location	Cultivar	Virulence combination (OMV-)
NIAB Region		
Central		
Headley Hall, North Yorkshire	Dula, Aberglen, Valiant, Rhiannon, Melys, Minerva, Bruno, Neon, Piper, Ripon	1,2,3
North East		
Cockle Park, Northumberland	Valiant, Ripon	1,2,3
Kelso	Spring Oat	1,2,3
South West		
Dyfed	Volunteer	1,2,3

CROWN RUST OF OATS

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Twenty-four samples of oat crown rust were received in 1995. Isolates of *Puccinia coronata avenae* were cultured from 23 of these and tested on the International Set of 10 differential cultivars. Details of the samples received and the races identified are given in Table 1.

Table 1 Locations and cultivars from which crown rust samples were received in 1995 with race identified for each sample.

Location	Cultivar	Race
St Clears, Dyfed	Winter Oats (15)	251
	Winter Oats (3)	289
	Winter Oats (2)	275
Aberystwyth, Dyfed	Appler	Failed
	Cc4146	251
Dyfed	Volunteer	251
Aberdeen	Spring Oat	251

Results

Three races were detected although the cultures appeared to comprise a mixture of races. The commonly occurring race 251 was identified in 18 samples and carries virulence to the differential cvs Appler, Bond and Saia. Race 289 which carries virulence to cvs Appler and Saia only has been detected in previous years, albeit at low frequencies. The other race identified was 275 which has also been identified previously at low frequencies in the pathogen population.

All varieties on the NIAB Recommended List of Winter and Spring Oats are susceptible to crown rust.

Table 2. Virulence spectra of races identified from the 1995 survey

Differential variety	Race		
	251	289	275
Anthony	R	R	R
Victoria	R	R	R
Appler	S	S	S
Bond	S	R	S
Landhafer	R	R	R
Santa Fé	R	R	R
Ukraine	R	R	S
Trispernia	R	R	R
Bondvic	R	R	R
Saia	S	S	S
Number of isolates	18	3	2

R = resistant S = susceptible

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1996

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. A scheme for brown rust of wheat was introduced in 1992. The schemes which follow update those in the last Annual Report.

The 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 is 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.

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 largely non-virulence 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 and Jenkins (1981).

REFERENCES

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

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

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

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST IN WHEAT. 1996.

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 good resistance are grown. The spread of disease can be further limited by growing different varieties in neighbouring fields, provided that the varieties 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).
2. Find this DG under 'Chosen DG' down the left hand side of the table.
3. Read across the 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	DG1 contd	DG7	DG0
Buster	Axona (S)	Consort	Genesis
Cadenza	Chablis (S)	Hereward	Soissons
Caxton	Imp (S)	Spark	Avans (S)
Charger	Shiraz (S)		Baldus (S)
Dynamo		DG9	Canon (S)
Encore	DG2	Beaufort	Minx (S)
Flame	Haven	Brigadier	Palermo (S)
Hunter	Rialto	Chianti	Promessa (S)
Magellan		Hussar	
Mercia	DG3	Reaper	
Raleigh	Riband		

(S) = spring wheat

	Companion DG					
Chosen DG	**1**	**2**	**3**	**7**	**9**	**0**
1	+	+	+	+	+	+
2	+	**Y**	y	y	y	**Y**
3	+	y	**Y**	y	+	**Y**
7	+	y	y	**Y**	+	**Y**
9	+	y	+	+	**Y**	**Y**
0	+	**Y**	**Y**	**Y**	**Y**	**Y**

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

March 1996

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF BROWN RUST IN WHEAT. 1996.

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 good resistance are grown. The spread of disease can be further limited by growing different varieties in neighbouring fields, provided that the varieties 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, in conjunction with the scheme for yellow rust.

Choosing varieties to grow together

1. Select first-choice variety and locate its Diversification Group (DG).
2. Find this DG under 'Chosen DG' down the left hand side of the table.
3. Read across the table to find the risk of disease spread for each companion DG.
   + = low risk of spread of yellow rust
   B = high risk of spread of yellow rust
   b = moderate risk of spread of yellow rust
4 Wherever possible choose combinations of varieties marked '+'. A combination marked 'b' is a lesser risk than one marked '**B**'.

DG1	**DG1 contd**	**DG7**	**DG0**
Beaufort	Canon (S)	Consort	Haven
Brigadier	Chablis (S)	Hereward	Mercia
Cadenza	Promessa (S)	Spark	Rialto
Encore	Shiraz (S)		Riband
Flame		**DG9**	Alexandria (S)
Genesis	**DG4**	Dynamo	Tonic (S)
Hunter	Soissons		Scamp (S)
Hussar		**DG10**	Imp (S)
Axona (S)	**DG5**		Minx (S)
Baldus (S)	Buster	Avans (S)	

(S) = spring wheat

	Companion DG						
Chosen DG	**1**	**4**	**5**	**7**	**9**	**10**	**0**
1	+	+	+	+	+	+	+
4	+	**B**	b	b	b	b	**B**
b	+	b	**B**	b	b	b	**B**
7	+	b	b	**B**	b	b	**B**
9	+	b	b	b	**B**	b	**B**
10	+	b	b	b	b	**B**	**B**
0	+	**B**	**B**	**B**	**B**	**B**	**B**

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

VARIETAL DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY 1996

Severe infection may result if mildew spreads between varieties which are susceptible to the same races of the pathogen. This risk is reduced if varieties with good resistance are grown. The spread of disease can be further limited by growing different varieties in neighbouring fields, provided that the varieties 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 the table.
3. Read across the table to find the risk of spread of mildew for each companion DG

   \+ = Low risk of spread of mildew

   M = High risk of spread of mildew

DG1
Fighter (W)
Alexis (S)
Chariot (S)
Chieftain (S)
Dandy (S)
Derkado (S)
Felicie (S)
Hart (S)
Pitcher (S)
Riviera (S)
Tankard (S)
Trinity (S)

DG4
Pipkin (W)
Brahms (S)
Camargue (S)
Tyne (S)

DG7
Brewster (S)
Chad (S)
Cork (S)
Cooper (S)
Delibes (S)

DG8
Manitou (W)
Nomad (S)

DG 9
Optic (S)

DG 10
Epic (W)
Gaelic (W)
Gleam (W)
Sunrise (W)

DG0
Angora (W)
Fanfare (W)
Halcyon (W)
Hanna (W)
Intro (W)
Linnet (W)
Marinka (W)
Melanie (W)
Muscat (W)
Pastoral (W)
Prelude (W)

DG0 contd
Puffin (W)
Regina (W)
Sprite (W)
Target (W)
Tokyo (W)
Prisma (W)

(W) winter barley (S) spring barley

	Companion DG						
Chosen DG	**1**	**4**	**7**	**8**	**9**	**10**	**0**
1	+	+	+	+	+	+	+
4	+	M	+	M	M	+	M
7	+	+	M	+	M	M	M
8	+	M	+	M	+	+	M
9	+	M	M	+	M	M	M
10	+	+	M	+	M	M	M
0	+	M	M	M	M	M	M

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