U.K. CEREAL PATHOGEN VIRULENCE SURVEY

1994 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 1994

Mildew of wheat

Virulence factors corresponding to the resistance factors present in current commercial winter wheat cultivars were mostly recorded at high levels, in excess of 70%. As in 1992 and 1993, the most frequently occurring pathotypes were able to infect most of the current cultivars. There is no clear evidence of a change in sensitivity to fenpropimorph in the wheat mildew population, However, some isolates show a reduced level of sensitivity compared to the control isolates.

Yellow rust of wheat

Although there were indications of virulence for Rendezvous (WYV 17) and the related cultivars Brigadier and Hussar at the seedling stage, all three remained as adult plants. Cadenza remained resistant to all isolates at the adult plant stage, including one isolate which was virulent on seedlings of the cultivar. The frequency of isolates with virulence for Hereward has not increased and was at around 10% in the 1994 survey.

Brown rust of wheat

Wheat cultivars were classified according to their specific resistances from seedling and adult plant tests. Virulence for Hereward and Spark, identified in controlled environment tests in 1993, was confirmed in the field. An isolate from an infected leaf sample of Flame was virulent on a number of previously field-resistant cultivars in controlled environment tests. Further adult plant tests at NIAB suggest that changes in the wheat brown rust population first noticed in 1991 are now widespread, namely virulence for Pastiche, Soissons, Virtue and Buster. In general, isolates giving a high level of infection on Pastiche also gave a high level of infection on Soissons, and isolates giving a high level of infection on Virtue gave a high level of infection on Buster. One isolate, tested for the first time in 1994, gave low, but significant, infection on Andante, Flame and Lynx, which have previously been highly resistant to brown rust.

Mildew of barley

Virulences corresponding to all widely used specific resistances were recorded at high frequencies. Virulence for *mlo* was not detected, although increasing reliance is being placed on this resistance in spring barley. The barley mildew population has retained a high level of complexity, similar to that seen in recent years, which continues to reduce the opportunities for varietal diversification. In Northern Ireland, there was little significant change from previous years. However, the large increase in BMV 7 (*Va1*) noted in 1993 was not repeated. There was an increase in frequency of the combined virulence BMV 4,10 (*Vla, Va13*) and a continued decline of BMV 4,6 (*Vla, Vk*). Limited tests for sensitivity to fenpropimorph gave no indication of any change in the mildew population compared to similar tests carried out in 1991 and 1994. The level of resistance to Baytan seed-treatment continued to decline. However, it is cleat that the current level is still considerably higher than in the 1970s.

Yellow rust of barley

Yellow rust of barley continues to be rare in the UK. Six samples were received, but only one was in suitable condition for testing. This possessed the virulence combination BYV 1,2,3.

Brown rust of barley

Seedling tests showed that the isolates carried a range of virulence factors in various combinations. The resistance of Cebeda Capa (Pa7) remains effective.

Rhynchosporium of barley

The 1994 CSL/ADAS disease survey recorded Rynchosporium at its highest level since 1988. The majority of spring barley cultivars on the UK Recommended List were susceptible in field and glasshouse tests, The spring barley cultivar Digger was highly resistant in adult plant tests, but some 1994 isolates induced higher levels of infection (5-10%) in seedling tests than previous isolates. Several winter barley cultivars displayed good levels of resistance in field nurseries.

Net blotch of barley

Several of the leaf samples received in 1994 displayed spotting or large circular lesions although the susceptible cultivars used in seedling tests gave netting type symptoms to these and all other isolates tested. Adult plant tests in the glasshouse indicated that some spring barley cultivars were resistant to both isolates used. Preliminary studies indicated that glasshouse tests will allow assessment of cultivars to be carried out more precisely and reproducibly than is possible with field tests.

Fungally transmitted mosaic viruses of barley

56% of samples contained barley yellow mosaic virus (BaYMV) and 60% barley mild mosaic virus (BaMMV). As before, BaMMV was more frequent on malting cultivars and BaYMV predominated amongst cultivars used for feed. One new "resistance-breaking" outbreak of BaYMV was reported.

Mildew of oats

All isolates tested in 1994 were identified as Race 5 (OMV 1,2,3). This race has increased in frequency over a number of years at the expense of the less widely virulent races 2, 3 and 4.

Crown rust of oats

Isolates from a batch of samples from Devon were identified as the common race 251. The remaining isolates, from two locations, appeared to comprise a mixture of races.

SURVEYS OF WINTER WHEAT AND WINTER BARLEY DISEASES IN ENGLAND AND WALES 1994

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Winter wheat

407 randomly selected fields of winter wheat were sampled in the 1994 disease survey undertaken jointly by CSL and ADAS. The fields were identified using a farm list stratified by the area of wheat grown in each region, and samples taken in July when crops were at the milky-ripe growth stage (GS 73-75). Levels of all foliar diseases were very low and similar in total to those recorded in the low disease years of 1990 and 1992. Although Septoria tritici was again the most severe foliar disease, the levels recorded were the lowest since 1990, with, on average, only 1.2% of the second leaf being affected. Septoria nodorum affected 0.3% of leaf 2. It was slightly less common than in 1993 in all regions except the south-west, but was relatively widespread compared to other recent years. in the north it was more common than S. tritici and in the south-west it reached its highest level for 7 years. Mildew was at its lowest level since 1989 affecting 0.4% of leaf 2. Brown rust was of little importance nationally, affecting only 0.1% of leaf 2 although in the extreme south-east, levels were higher at 0.6%. Yellow rust was recorded in only 15 samples, 8 of which were from the eastern region.

8.9% of stem bases were affected by moderate or severe eyespot symptoms, the lowest level recorded since 1990, while sharp eyespot was less severe than in any previous survey with damaging symptoms affecting only 1.4% of stems. Stem base fusarium was also less prevalent compared to 1993, with moderate or severe nodal and internodal symptoms occurring on 6.6% and 3.6% of stems respectively. The incidence of fusarium ear blight was lower than in any of the past 3 years, with the disease being recorded in 5.2% of samples with 0.3% of ears affected in total. Take-all was less important than in any year since records for this disease began in 1987, with take-all patches being seen in only 5.9% of crops. BYDV was less frequent than in 1993, with symptoms being recorded in 14.8% of crops.

Winter barley

383 randomly selected fields of winter barley were sampled in the 1994 disease survey undertaken jointly by CSL and ADAS. The fields were identified using a farm list stratified by the area of winter barley grown in each region, and samples taken in June and early July when crops were at the watery-ripe to early-mild stage (GS 71-73). Total foliar disease levels were lower than in any previous survey. Mildew was the most severe foliar disease, but affected only 1.9% of the second leaf, the lowest level recorded since 1990. The only major disease to show an increase compared to the previous year was rhynchosporium which affected 1.7% of leaf 2, the highest level of

this disease seen since 1988. It was particularly prevalent in the south and west where over 90% of crops were affected. Net blotch was less severe than in 1993, affecting 0.9% of the second leaf, with the highest level occurring in the south-west. Brown rust was less important than at any time in the past 8 years, affecting on average only 0.3% of leaf 2. Of the minor foliar diseases, septoria was less common than in 1993, but halo spot which was recorded in 11 crops, mainly in Wales and the south-west, and yellow rust which was seen in 7 crops were both more frequent than for several years.

11.6% of stem bases were affected by moderate or severe eyespot symptoms, less than half the number recorded in the previous year, and sharp eyespot was less severe than in any previous survey. Stem base fusarium was also less severe than for many years, with moderate or severe nodal and internodal symptoms occurring on 4.5% and 0.9% of stems respectively. BYDV symptoms were recorded in 13.8% of crops compared to 6.9% in the previous year.

MILDEW OF WHEAT

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Virulence factors corresponding to the resistance factors present in current commercial winter wheat cultivars were mostly recorded at high levels, in excess of 70%. The most frequently occurring pathotypes were able to infect most of the current cultivars. This is similar to the results of the surveys carried out in 1992 and 1993.

INTRODUCTION

The powdery mildew epidemic was slow to build up on winter wheat in 1994, probably due to the cool, wet spring and subsequent hot, dry June. Much of the sampling was carried out at least two weeks later than in 1993. Many of the current winter wheat cultivars have good non-specific resistance which, together with the unfavourable weather conditions for mildew, resulted in generally low levels of infection in the field.

METHODS

A total of 256 samples of wheat mildew were received in 1994, mostly from trial plots. Single colony isolates were successfully cultured from 181 samples. The isolates were taken from infected leaves of the following cultivars:

Winter cultivars	No. of isolates		No. of isolates		No. of isolates
Andante	9	Haven	18	Beaufort	10
Genesis	13	Hunter	25	Lynx	5
Hereward	7	Buster	13	Zodiac	5
Prophet	12	Dynamo	12	Turpin	17
Rialto	10	Brigadier	19	Mercia	15
Galahad	2	Hussar	12	Spark	20
Norman	2	Consort	7	Cadenza	15
Flame	12	Riband	10	Soissons	10
Beaver	20	Admiral	3	4 cultivars with unknown resistance	8
Encore	10	Apollo	6		
Spring cultivars					
Alexandria	2	Scamp	2	Baldus	4
Promessa	2	Axona	4		
Tonic	4	Canon	2		
Total	347				

The samples were collected from the following locations:

	No. of isolates		No. of isolates
Romney Marsh, Kent	2	Bourne, Lincs.	2
Bridgets, Hants.	1	Ledbury, Glos.	2
Harpenden, Herts.	28	Rosemaund, Hereford & Worcs	33
Ickleton, Cambs.	25	Dyfed, Wales	1
Thriplow, Cambs.	28	Headley Hall, Yorks.	32
NIAB, Cambridge	104	High Mowthorpe, Yorks	2
Ely, Cambs	2	Cockle Park, Northumb.	6
Bury St. Edmunds, Suffolk	16	Aberdeen, Scotland	29
Kirton, Lincs.	2	Craibstone, Scotland	32
Total	347		

A further 52 samples failed to produce viable conidia, and 23 isolates taken from infected leaves of cultivars with unknown resistance were not tested.

The differential cultivars used to test the isolates for virulence factors are shown in Table 1. The European codes for resistance and virulence have been used throughout this report according to the proposals made by Boesen *et al.* (in press).

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
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?)

* Flanders previously designated *Mli*, but *Pm5* and *Mli* are now considered to be synonymous.

RESULTS

Virulence frequencies

The results of the 1994 survey are shown in Table 2, together with those from the previous four years. The frequencies of V2 (WMV2), V4b (WMV4), V5 (WMV5), V6 (WMV6) and V8 (WMV7) remained at high levels as recorded in 1993. These virulence factors correspond to the resistance factors present in most current winter wheat cultivars and also many of those which have been widely grown over the past few years. The high level of virulence for MlTa2 (WMR'Talent') recorded in 1993 was also maintained although the only selection for this virulence is the declining area of Mercia, currently about 3% of the area of winter wheat in the U.K. The frequency of VMlTa2 has increased gradually over the last five years.

There has been a small increase in the frequency of VTo (WMVp), back to the level detected in 1992. This could be the result of increased selection by the winter cultivar Spark which carries the resistance factor MlTo (WMRp), previously only found in spring wheats.

The frequencies of VSi2 (WMVr) and VSo (WMV'Sona') have decreased to their lowest levels for five years. There is very little selection for these virulence factors as the corresponding resistances occur only in spring wheat cultivars.

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

	Frequency of virulence factors (%)				
Virulence factor	1990	1991	1992	1993	1994
2	99	100	99	98	99
4b	52	69	73	79	84
5	-	92	90	95	92
6	69	80	76	78	80
8	66	80	86	93	93
d	-	-	27	15	20
2,Ta2	-	54	60	80	82
5,Ta2	34	50	60	79	76
To	-	9	24	18	24
Br	-	-	31	20	27
5,Si2	-	38	32	39	26
So	-	-	23	22	21
Ax	-	10	17	10	14
Number of isolates tested	290	300	194	356	347

The frequencies of Vd (WMV9) and VAx (WMV'Axona') increased slightly in 1994, which may be the result of increasing popularity of Cadenza which carries MlAx (WMR'Axona') and possibly Mld (WMR9). However, the frequencies of Vd and VAx have fluctuated over the past few years and the total area of Cadenza may be too small to have much influence. The frequency of VBr (WMVq) also showed a slight increase from the level detected in 1993, but again the frequency of VBr has fluctuated over the last three years. It is possible that this could also be associated with the cultivar Cadenza, since all isolates so far identified as virulent on this cultivar also carry VBr.

Table 3 shows the frequencies of the most commonly identified pathotypes in 1992, 1993 and 1994. The frequencies over the three year period are very similar. The pathotype V2,4b,5,6,8,Ta2 (previously labelled WMV2,4,5,6,7,Talent) occurs most often and represents about 25% of the population. It is able to infect 14 of the 17 winter wheat cultivars on the Recommended List. The remaining 70 pathotypes identified in 1994 occurred at a much lower level, many in only one isolate.

Table 3. Frequencies of the most commonly identified pathotypes in 1992, 1993 and 1994 as defined by the differential cultivars listed in Table 1.

	Frequency of pathotypes (%)		
Pathotype *	1992	1993	1994
4b,5,6,8	14	6	8
5,8,Ta2	4	3	3
4b,5,8,Ta2	2	4	4
4b,5,6,8,Ta2	8	25	26
4b,5,6,8,Ta2,To,Br	3	4	5
5,8.Ta2,Si2,So	3	1	3
4b,5,6,8,Ta2,Si2,So	4	8	6
4b,5,6,8,d,Ta2,To,Br,Ax	3	2	3
Number of pathotypes	78	78	71
Number of isolates	194	356	347

* All pathotypes also carry V2

Table 4 compares the complexity of the mildew populations able to infect the new winter cultivars Spark (MlTo) and Cadenza (MlAx). The resistance factors of both of these cultivars were previously present in spring cultivars only. Virulence factor VTo occurs more frequently than VAx (24% and 14% respectively, see Table 2), but the isolates infecting Cadenza are more complex than those infecting Spark, the majority carrying at least 9 virulence factors.

Table 4. Number of virulence factors carried by isolates capable of infecting Spark and Cadenza in 1994.

No. of virulence factors	Percentage of isolates with each number of virulence factors	
	Spark	Cadenza
6	4	0
7	17	6
8	25	4
9	18	26
10	20	34
11	8	15
12	8	15
No. of isolates	84	47
No. of pathotypes	24	18

Table 5 shows the proportion of the wheat mildew population screened in 1994 that is able to infect the cultivars in Recommended List trials in 1994. Of the 20 cultivars listed, 17 can be infected by over 70% of the population. Only Cadenza and Spark remain resistant to the bulk of the population. Soissons also has good resistance to mildew in the field (resistance rating of 8) but the resistance factors present in Soissons are unknown.

Table 5. The proportion of mildew isolates tested in 1994 able to infect winter wheat cultivars in Recommended List trials.

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Brigadier	76	Consort	76
Hussar	76	Beaufort	76
Hunter	93	Dynamo	80
Riband	76	Encore	93
Genesis	100	Cadenza	14
Hereward	100	Flame	84
Spark	24	Turpin	68
Mercia	78	Beaver	93
Rialto	100	Haven	93
Buster	80	Admiral	93

Resistance Factors in New Cultivars

The specific resistance factors identified in winter wheat cultivars are shown in Table 6. No new resistance factors were detected in cultivars tested in 1994.

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

None	**Pm2,Pm4b,Pm8**	**Pm4b,Pm6 (Pm2?)**	**Pm5,MlTa2**
Genesis	Apollo	Hussar	Mercia
Hereward		Brigadier	
Prophet	**Pm2,Pm6**		**MlTo**
Rialto	Buster	**Pm6,Pm8**	Spark
Andante	Dynamo	Zodiac	
		Lynx	**MlAx (Mld,MlBr?)**
Pm4b	**Pm2,Pm4b,Pm6**	Beaufort	Cadenza
Flame	Riband		
	Consort	**Pm4b,Pm6,Pm8 (Pm2?)**	**Unknown**
Pm8		Turpin	Soissons
Beaver			
Haven			
Hunter			
Encore			

Tests for sensitivity to fenpropimorph

Tests to determine the sensitivity of isolates to fenpropimorph were carried out using a sample of 89 isolates, selected randomly from those collected in 1994. The tests were carried out in two batches, with the five control isolates used in 1991 and 1993 included in each batch. Seedlings were sprayed with various rates of the fungicide, the leaves detached after 24 hours and inoculated with conidia. Assessments were made after 10 days incubation, using a 0 - 4 scale for leaf area infected with mildew.

Table 7 shows the results of the tests carried out in 1994. Direct comparisons between the two test batches cannot be made, but isolates can be compared with the controls in the same batch.

The isolates in the first batch do not appear significantly less sensitive than the insensitive controls, collected in 1991. In the second batch, the control isolates gave less infection than in the first test and there was no difference between the sensitive and insensitive controls. Some of the isolates in batch 2 appeared less sensitive than the controls, particularly the isolate from Ledbury, Hereford. However, due to the limited number of isolates tested and the variability of these tests, the results should be interpreted with caution.

Table 8 compares the results of the tests carried out in 1994 with those of 1991 and 1993. Again, the variability of the control isolates can be seen, appearing to be more sensitive in 1994. Allowing for the limited size of the samples tested, there is no clear evidence of any large changes in the population. However, should the incidence of isolates such as the one from Ledbury increase, there is the possibility of a trend towards reduced sensitivity to fenpropimorph.

Table 7. Sensitivity of wheat mildew isolates collected in 1994 to fenpropimorph.

		Growth as % of growth on untreated leaves			
		Rate of fenpropimorph as proportion of field rate			
Location	No. of isolates	0.01	0.02	0.05	0.1
Batch 1					
Aberdeen	3	10	0	0	0
Bury St. Edmunds	7	26	1	0	0
Cambridge	8	29	1	0	0
Craibstone, Scotland	7	28	4	0	0
CSL, Harpenden	6	25	1	0	0
Headley Hall	8	22	2	0	0
Ickleton, Cambs	5	5	0	0	0
Thriplow, Cambs	1	7	0	0	0
Sensitive controls	3	0	0	0	0
Insensitive controls	2	20	0	0	0
Batch 2					
Bourne, Lincs	2	0	0	0	0
Cambridge	9	2	0	0	0
Cockle Park	2	18	0	0	0
Craibstone, Scotland	1	0	0	0	0
Ely, Cambs	2	0	0	0	0
Headley Hall	3	32	0	0	0
Kirton, Lincs	1	31	0	0	0
Ledbury, Hereford	1	70	48	0	0
Rosemaund	11	26	1	0	0
Thriplow, Cambs	12	29	2	0	0
Sensitive controls	3	0	0	0	0
Insensitive controls	2	0	0	0	0

Table 8. Sensitivity of isolates collected in 1991, 1993 and 1994 and the control isolates to fenpropimorph.

			Growth as % of growth on untreated leaves			
			Rate of fenpropimorph as proportion of field rate			
Year	Isolates	No. of isolates	0.01	0.02	0.05	0.1
1991	sample	19	51	33	36	7
	sens. controls	3	0	0	0	0
	insens. controls	2	93	96	11	0
1993	sample	46	22	6	0	0
	sens. controls	3	0	0	0	0
	insens. controls	2	36	0	0	0
1994	sample	89	22	1	0	0
	sens. controls	3	0	0	0	0
	insens. controls	2	6	0	0	0

CONCLUSIONS

Most of the virulences corresponding to the resistance factors carried by current winter wheat cultivars were recorded at high frequencies in 1994. Only Spark and Cadenza remain resistant to the majority of pathotypes, and none of the new cultivars tested in 1994 carry new specific resistance factors. This general picture of the wheat mildew population relative to the resistances in the host population has existed for several years, and it is therefore important that the high level of non-specific resistance found in many current cultivars is maintained.

REFERENCES

Boesen, B., M. S. Hovmøller and J. H. Jørgensen (in press). Designations of barley and wheat powdery mildew resistance and virulence in Europe. *Proceedings of the 3rd. Cereal Mildew Workshop, 1994.*

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

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

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

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

YELLOW RUST OF WHEAT

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Virulences corresponding to the specific resistances WYR 1, WYR 2, WYR 3, WYR 4, WYR 6, and WYR 9 remained at high frequencies. Virulence for Carstens V was detected in more than 50% of isolates and virulence for Hereward in 10%. Virulence was detected at the seedling stage for Rendezvous (WYR 17) and the related cultivars Brigadier and Hussar, but all three cultivars maintained a very high level of resistance as adult plants.

SEEDLING TESTS OF 1994 ISOLATES

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

The incidence of yellow rust in the UK in 1994 was low. 68 isolates of *P. striiformis* were tested for virulence on seedlings of the differential cultivars listed in Table 1. The isolates originated from 28 different cultivars. 49 isolates were from naturally infected plots or crops and 19 from inoculated plots.

Seedling virulence frequencies, based on isolates from naturally infected crops and plots, are given in Table 2. The frequencies of WYV 2, WYV 3, WYV 4 and WYV 9 remained high whereas the frequencies of WYV 1 and WYV 6 appeared to decline. There was an decrease in the frequency of virulence for Carstens V and cultivars with related resistance (Talon and Hereward). Virulence for Rendezvous (WYR 17) was detected more frequently than for Brigadier and Hussar, the other two cultivars possessing WYR 17. Virulence was not detected for WYR 8, nor for Tonic, Cadenza or Parade.

Virulence frequencies for isolates taken from inoculated plots are given in Table 3. Numbers of re-isolates were too small to make a meaningful comparison of frequencies with isolates from natural infection, but it is significant to note that two re-isolates possessed virulence for Tonic and Cadenza.,

Table 1. Differential cultivars used in seedling virulence tests in 1994

Differential Cultivar	WYR Factor	Gene	Cultivar Code
Main set			
Chinese 166	WYR 1	Yr 1	
Heine 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 Rx (CV)		CV
Talon	WYR Rx (CV+?)		Ta
Hereward	WYR Rx (CV+?)		He
Rendezvous	WYR 17	Yr 17	Re
Brigadier	WYR 17 +?	Yr 17 +?	Br
Hussar	WYR 17 +?	Yr 17 +?	Hu
Tonic	WYR Rx (Tonic)		To
Cadenza	WYR Rx (Tonic)		Ca
Parade	WYR Rx		Pa
Hornet	WYR 6,9	Yr6 + Yr9	

* O = Overall A = Adult Plant ? = unknown

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

Year	'80	'81	'82	'83	'84	'85'	'86	'87	'88	'89	'90	'91	'92	'93	'94
WYV 1	95	71	63	85	75	76	78	87	68	62	85	91	88	89	65
WYV 2	100	100	100	100	100	100	100	100	100	100	100	100	100	98	100
WYV 3	85	95	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 4	15	29	37	20	31	45	70	47	78	97	91	86	86	89	86
WYV 6	25	31	29	26	64	90	96	89	72	57	69	64	88	68	41
WYV 7	0	5	5	0	3	3	22	8	6	2	9	19	7	8	4
WYV 8	0	0	2	0	0	*	*	*	*	*	*	0	0	0	0
WYV 9	0	5	2	23	31	3	4	5	66	99	94	88	76	84	94
<u>Virulence for cultivars in additional set</u>															
Carstens V														75	55
Talon												41	38	60	55
Hereward												36	47	35	10
Rendezvous															57
Brigadier													40	35	10
Hussar												12	29	32	6
Tonic													1	2	0
Cadenza													0	2	0
Parade													3	0	0
No. of isolates	20	42	41	63	36	29	23	52	71	156	67	42	77	63	49

Table 3. Virulence factor frequency % (re-isolates from inoculated plots, 1994)

WYV 1	74	Talon	53
WYV 2	95	Hereward	37
WYV 3	100	Rendezvous	68
WYV 4	79	Brigadier	21
WYV 6	79	Hussar	11
WYV 7	5	Tonic	11
WYV 8	0	Cadenza	11
WYV 9	68	Parade	0
Carstens V	47		

total no. re-isolates = 19

ADULT PLANT TESTS OF 1993 ISOLATES

18 isolates (Table 4) were tested for virulence on adult plants of 30 cultivars in Polythene tunnels and on seedlings of cultivars with previously unidentified resistances. 17 of the isolates were chosen from those collected during the 1993 survey, on the basis of their seedling virulence characteristics and source cultivar.

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

Isolate	Source		WYV	Additional
code	Cultivar	Location	Factors	virulence*
93/1	Hereward	Kent	1,2,3,4,6	CV,Ta,He
93/24	Hereward	Cambs	1,2,3,4,6	CV,Ta,He
93/8	Promessa	Cambs	2,3,4,6	CV,Ta,He
91/601	Hereward	Cambs	2,3,4,6	CV,Ta,He
93/21	Cygnus	Cambs	3,4	CV,Ta,He
93/26	Talon	Cambs	2,3,4,6	CV,Ta,He
93/13	Soissons	Cambs	1,2,3,4,6,9	CV,Br,Hu
93/33	Brigadier	Cambs	1,2,3,4,9	CV,Br,Hu
93/44	Brigadier	Lincs	1,2,3,4,9	CV,Ta,He,Br,Hu
93/36	Soissons	Cambs	1,2,3,4,6,9	CV,Ta
93/34	Brigadier	Cambs	1,2,3,4,6,9	CV,Ta,Hu
93/38	Hunter	Cambs	1,2,3,4,6,9	CV,Ta
93/54	CWW 92/57	Scotland	1,2,3,4,6,9	Ta,Br,Ly
93/18	Rascal	Kent	1,2,3,4,9	CV,Ta,Hu,Br
93/37	Admiral	Cambs	1,2,3,4,7,9	CV,Ta,He,Br,Hu
93/20	Admiral	Lincs	1,2,3,4,6,9	CV,Ta,Hu,Br,Ly
93/10	Rialto	Cambs	2,3,4,6,7,9	To,Ca
93/58	Genesis	Cambs	1,2,3,4,7,9	CV,Ta,He,Br,Hu

* cultivar codes as in Table 1 with addition of Ly = Lynx.
Rendezvous (Re) was not included in seedling virulence tests in 1993

Adult plant results are given in Table 5

Rendezvous, Hussar, Brigadier, Andante and Lynx, cultivars which are assumed to possess the resistance WYR 17 derived from VPM, remained resistant as adult plants, despite indications of virulence at the seedling stage. Trace levels of infection were detected with a few of isolates, but these were not necessarily isolates which had shown virulence for seedlings of the cultivars. None of the three isolates collected from plots of Brigadier was virulent on adult plants of this, or related, cultivars, supporting the suggestion that the isolated infected plants from which the samples had been taken were off-types.

Cadenza remained resistant to all isolates at the adult plant stage, although one isolate, 93/10, was virulent on seedlings of the cultivar. Zodiac, Prophet, Flame, Buster, Hunter and Mercia retained high levels of resistance to all isolates.

The first six isolates in Tables 4 and 5 were virulent both on seedlings and adult plants of Spark, Talon and Hereward and on seedlings of Carstens V, although a number of other isolates with apparent virulence for seedlings of these cultivars failed to infect adult plants. The first three of the six isolates gave substantially higher levels of infection on Hereward than the second three isolates.

Five cultivars at the bottom of the table were included in polythene tunnel tests for the first time in 1994. All displayed a high level of resistance, although Encore was infected to a slight degree by certain isolates. In contrast to the results of these tests, low levels of infection have been recorded in spreader beds on Consort, when inoculated by some isolates with virulence for Hereward.

Virulence for the adult plant resistances WYR 13 and WYR 14 was common and found in combination with virulence for Talon and Hereward.

Mean infection levels on Soissons were low. However, isolate 93/1 gave an infection level of 12% on this cultivar towards the end of the season. This 'late rusting' effect on Soissons was also observed in spreader beds in 1994.

Resistances represented by the main seedling differential set, WYR 1-4, WYR 6, WYR 7 and WYR 9 have now been matched singly and in complex combinations by the UK population of *P. striiformis* and the frequencies of corresponding virulences are high. Virulence for WYR 8 has been detected rarely, but, if the resistance were to be incorporated into new cultivars, it is likely that the corresponding virulence would increase. The only resistance in this set for which virulence has not been detected, WYR 5, is unlikely to be used as a resistance source by breeders. The resistance of new cultivars and breeding lines is based largely on other sources, some of which are represented by cultivars in the additional set of seedling differentials and some of which are probably adult plant resistances. It is therefore vital to monitor these 'additional' resistances closely for the first signs of increased virulence. For example, an estimated 29% of the 1995 winter wheat acreage will be dependent on resistance derived from Rendezvous for protection against yellow rust. Rendezvous entered official trials in 1984, but was grown on only a very small scale. It is now, with the resistance exposed on a substantial proportion of the wheat acreage, that its durability will be put to the test.

REFERENCES

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

Table 5 **Adult Plant tests 1994. Mean per cent leaf area infection (mean of 4 assessments)**

Virulence in seedling tests given in Table 4

Cultivar	WYR factors	93/1	93/24	93/8	91/601	93/21	93/26	93/13	93/33	93/44	93/36	93/34	93/38	93/54	93/18	93/37	93/20	93/10	93/58
Rendezvous	WYR 17	tr	tr	0	0	0	0	0	0	0	0	0	0	tr	tr	0	0	0	0
Hussar	WYR 17	tr	0	0	0	0	0	0	0	0	0	0	0	0	tr	1	0	0	0
Brigadier	WYR 17	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Andante	WYR 17	tr	tr	0	tr	0	0	0	0	0	0	0	0	0	tr	0	0	0	0
Lynx	WYR 17	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	tr	0	0	0
Cadenza	RTonic + APR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Zodiac	R	0	0	0	0	0	tr	0	0	0	tr	0	0	0	tr	tr	0	0	0
Prophet	0+ APR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Flame	Rx+APR	1	1	0	0	0	0	0	tr	tr	0	0	0	tr	0	0	0	0	0
Buster	R Parade+APR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hunter	6,9+APR	3	tr	0	0	tr	tr	0	tr	tr	0	tr	1	2	tr	tr	0	0	tr
Mercia	3+APR	3	tr	1	0	1	0	0	0	0	0	0	0	tr	1	0	tr	0	0
Soissons	Rx+APR	4	1	tr	0	1	1	0	0	tr	0	0	tr	1	2	tr	tr	0	0
Talon	CV+	25	22	27	12	31	25	24	1	0	1	1	0	0	1	2	3	0	0
Hereward	CV+	9	10	11	2	4	4	0	tr	tr	0	0	0	0	tr	0	0	0	0
Spark	CV+	10	5	6	3	2	3	0	tr	tr	0	1	1	2	1	0	0	0	0
M Huntsman	2,13	26	8	1	0	2	2	1	4	6	2	tr	6	10	18	11	1	tr	2
Hustler	1,2,13	34	21	5	0	25	14	12	10	21	13	3	20	22	30	18	16	1	3
Riband	13	24	8	4	0	9	3	3	5	3	1	1	12	11	21	15	1	1	2
Hobbit	14	32	25	25	13	37	15	4	8	12	10	11	14	21	13	20	4	1	14
Admiral	9	8	10	6	0	12	11	4	7	10	5	9	11	16	22	17	13	tr	15
Haven	6,9	20	7	6	tr	22	18	17	10	17	10	17	22	25	17	14	17	11	5
Beaver	6,9	20	6	9	1	22	18	14	13	16	10	16	19	24	11	11	9	2	1
Rialto	6,9	13	2	6	0	14	13	7	6	11	6	15	14	23	9	9	12	9	5
Genesis	0	12	6	4	tr	2	3	tr	3	2	2	0	tr	1	5	3	tr	0	tr
Encore	?6,9+	4	1	tr	0	1	tr	tr	1	2	1	1	2	4	1	1	2	1	0
Consort	?CV+	tr	0	0	0	0	0	tr	0	0	0	0	0	0	0	0	0	0	0
Beaufort	?6,9+	tr	tr	0	0	0	0	0	0	0	0	0	0	0	tr	0	0	0	0
Dynamo	Rx+	tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	tr
Turpin	?6,9+	tr	tr	0	0	0	0	0	0	1	0	0	tr	1	1	0	0	0	0

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

BROWN RUST OF WHEAT

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Seedling tests with the 1994 isolates identified the specific resistances of winter and spring wheat cultivars. Virulences to a number of 'resistant' cultivars identified in 1993/1994 controlled environment tests were not all confirmed in the field although virulence to cvs Hereward and Spark was. An isolate cultured from a leaf sample from cv. Flame was virulent on several highly resistant winter wheat varieties in controlled environment tests. The resistances of the spring wheat cultivars were effective against this isolate.

GLASSHOUSE SEEDLING TESTS WITH 1993 ISOLATES

Fifty-four samples of wheat brown rust were received in 1994. This number included 5 from the CSL/ADAS Cereal Disease Survey. The geographic origins of the samples are given in Table 1.

Table 1. Geographical origin of 1994 wheat brown samples

Location (NIAB region)	Number of samples
South East	
Norfolk	9
Cambridgeshire	6
Hertfordshire	4
Kent	3
Oxfordshire	3
South West	
Herefordshire	18
Dyfed	2
Somerset	1
Central	
Lincolnshire	3
Leicestershire	2
N. Yorkshire	2
W. Midlands	1

The samples were from a range of wheat cultivars (Table 2). They included samples taken from cvs Flame and Encore, grown at Barroway Drove, Norfolk, which displayed infection levels of up to 25%. These cultivars have previously been resistant in adult plant field tests at the NIAB, Cambridge and at IGER, Aberystwyth.

Table 2. Cultivars from which infected leaf samples were received in 1994.

Cultivar	Number of samples	Cultivar	Number of samples
Haven	12	Andante	1
Riband	10	Spark	1
Apollo	7	Hussar	1
Soissons	3	Buster	1
Slejpner	2	Campreny	1
Brigadier	2	Estica	1
Rialto	2	Dynamo	1
Hunter	2	Flame	1
Pastiche	1	Encore	1
Admiral	1	Promessa (S)	1
Beaver	1		
Mercia	1		

(S) = spring wheat

Table 3. Differential cultivars

Standard differentials (WBR-factor)	Thatcher Lr lines	Additional cultivars	
Clement (1)	Lr 1	Avans	Encore
Maris Fundin (2)	Lr 2a	Baldus	Hereward
Norman (2)	Lr 3	Promessa	Hunter
Hobbit (2)	Lr 3bg	Beaufort	Hussar
Sappo (3)	Lr 3ka	Brigadier	Shiraz
Maris Halberd (4)	Lr 9	Chablis	Turpin
Gamin (6)	Lr 15	Consort	Zodiac
Sterna (7)	Lr 19		
Sabre (7)	Lr 24		
Armada (0)			

Isolates obtained from 39 of the samples were tested on differential cultivars which comprised the standard WBR cultivars, cv. Thatcher backcross lines carrying different Lr resistance factors, and 14 additional spring and winter wheat cultivars (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).

Results

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

A virulence combination (WBV-6,7) which has not been detected in recent years was identified from 1 isolate. Isolates carrying these virulence factors have been identified previously but in the more complex combinations 2,6,7 and 1,2,6,7.

Cultivars Maris Fundin, Norman and Hobbit, which carry the temperature-sensitive resistance factor WBR-2, were again separated on their reactions to some of the isolates (Clifford *et al.*, 1982).

The temperature-sensitive resistance of cvs Sabre (WBR-7) and Sterna (WBR-7) which are effective at 25°C were overcome by 3 isolates. The remaining isolates were only virulent on these cultivars at 10°C. The reactions of the Thatcher-Lr backcross lines, which are known to carry specific Lr genes, to the 1994 isolates are given in Table 6.

Table 4. Virulence combinations and their frequencies identified from the 1994 isolates compared with the previous six years

WBV formula	Frequency						
	1988	1989	1990	1991	1992	1993	1994
6	0.04	0	0.02	0	0.06	0.04	0.3
1,6	0	0	0	0	0	0	0.03
2,6	0.96*	0.33	0.27	0.06	0.12	0.09*	0
6,7	0	0	0	0	0	0	0.03
1,2,6	0	0.67	0.67	0.82	0.76	0.75*	0.58
1,3,6	0	0	0	0	0	0.02	0
2,6,7	0	0	0.04•	0	0	0	0
1,2,3,6	0	0	0	0	0	0.06	0
1,2,4,6	0	0	0	0.06	0	0	0
1,2,6,7	0	0	0	0	0	0.04■	0.06
1,2,3,4,6	0	0	0	0.06	0.06	0	0
Number of isolates tested	26	12	51	18	17	53	39

* 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 CPV Surveys 1988-1994)

Cultivar	WBR factor	Frequency						
		1988	1989	1990	1991	1992	1993	1994
Clement	1	0	0.67	0.66	0.94	0.82	0.87	0.67
Fundin	2*	0.96	1.00	0.98	1.00	0.94	0.83	0.64
Norman	2*	0.85	1.00	0.98	1.00	0.94	0.94	0.49
Hobbit	2*	0.88	1.00	0.98	1.00	0.94	0.94	0.41
Sappo	3*	0	0	0	0.06	0.06	0.08	0
Halberd	4*	0	0	0	0.11	0.06	0	0
Gamin	6	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sterna	7*	0	0	0.04	0	0	0.04	0.08
Sabre	7*	0	0	0	0	0	0.02	0.08
Armada	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of isolates	36	26	12	51	18	17	53	39

*Temperature sensitive

Table 6 Virulence frequencies corresponding to each Thatcher-Lr backcross lines to 1994 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	0.36	0.81	0.06	0.06	0.21	0.62	0.94	1.00	1.00
R,MR	MS,S							0.03		
MS,S	R,MR	0.61	0.19	0.85	0.85	0.74	0.38			
MS,S	MS,S	0.03		0.09	0.09	0.05		0.03		

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

The Lr gene lines, Lr1, Lr2a and the Lr3 group expressed resistance to the majority of the isolates, with resistance being more frequently observed at the higher temperature. Isolates virulent on the Lr3 group were also virulent on cvs Sterna (WBR-7) and Sabre (WBR-7), although the Lr3ka line expressed resistance to one of these. The Thatcher Lr15 line was also susceptible to one of the WBV-7 pathotypes but was resistant to the remainder of the 1994 isolates.

The resistances of Lr19, Lr24 and Lr9 were effective, although some isolates were virulent on the latter at 10°C.

The additional spring and winter wheat cultivars expressed a range of responses to the 1994 isolates. These are summarised as follows:

Promessa: Resistant at 10°C and 25°C. One isolate induced fairly high levels of infection (35% of cv. Armada) at 25°C. This isolate was also the only one virulent on the Thatcher line Lr1 at the high temperature

Avans: Resistant to all isolates but resistance not effective against 9 isolates at 25°C.

Baldus: Low temperature resistance effective against half of the isolates.

Zodiac, Hunter, Turpin, Encore: All resistant to isolates lacking WBV-1. Susceptible to WBV-1 isolates except for 6 such pathotypes which infected cv. Zodiac only. Isolates identified as carrying WBV-1 but which have failed to infect cv. Hunter have been identified previously. Cultivar Encore expressed a mixed reaction (susceptible and resistant) to several of the WBV-1 isolates at 25°C.

Hussar, Brigadier, Beaufort: Resistance was expressed at both temperature regimes to the majority of the isolates, but the 3 cultivars were susceptible to isolates WBRS-94-30, 36 and 50. Cultivar Brigadier was susceptible to a further 4 isolates with cvs Hussar and Beaufort displaying a resistant reaction.

Chablis, Shiraz: The response of cv. Chablis to the isolates was similar to cvs Sterna (WBR-7) and Sabre (WBR-7), suggesting that it carries the temperature-sensitive resistance factor WBR-7. Cultivar Shiraz expressed resistance to all the 1994 isolates at both temperature regimes except to the 3 isolates identified as carrying WBV-7 to which it was susceptible at 25°C.

Consort, Hereward: Susceptible.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Forty-three winter and 12 spring wheat cultivars were sown in each of four nurseries in the 1993-1994 season using standard procedures. The nurseries were inoculated with either one of the following isolates of *P. recondita*.

Isolate	Origin
WBRS-93-56/1	WBRS-93-56 ex cv. Hunter, Kent
WBRS-91-65/1	WBRS-91-65 ex cv. Pastiche, Grantchester, Cambs
WBRS-93-80/1	WBRS-93-80 ex cv. Estica, Glympton, Oxon
WBRS-93-87/1	WBRS-93-87 ex cv. Hereward, NIAB, Cambs

These isolates may carry different virulence factors from those identified previously in the isolates from which they originated (Jones and Clifford, 1994).

Results

These are summarised in Table 7. High levels of disease built up on the spreader cultivars within the nurseries, although these levels were achieved less quickly in the nursery inoculated with isolate WBRS-93-56/1. Using data from the nurseries, together with results from previous years' adult plant tests, the wheat cultivars were classified into groups. Because some of the cultivars have been placed into a group solely on the basis of data from the 1994 isolation nurseries, it should not be interpreted that cultivars within a group carry a common resistance factor(s).

Group 1: Isolate WBRS-91-65/1 failed to infect cv. Clement (WBR-1), although isolate WBRS-91-65, from which it originated, was identified in 1991 seedling tests and in adult plant field tests in 1993 as carrying the corresponding virulence factor.

Group 1a: Cultivars within this group displayed similar patterns of response to the 4 isolates as cv. Clement. In previous years some host:pathogen reactions have indicated that these cultivars may carry WBR-1 plus additional resistance(s).

Group 1b: Cultivar Rialto is placed in this group as it responds similarly to the other Group 1 cultivars to the isolates but differs in its responses to some WBV-1 pathotypes.

Group 1c: The adult plant resistance of cv. Slejpner (WBR-1+APR) has been very effective against the pathotypes to which it has been tested, with only 1 isolate, WBRS-90-9, infecting it in the field (Jones and Clifford, 1992). Adult plant tests in controlled environments have identified 2 isolates virulent on cv. Slejpner (Jones and Clifford, 1994). Sub-isolates of these, WBRS-93-56/1 and WBRS-93-80/1, also infected it in the 1994 field nurseries.

Group 1d: Cultivars within this group are resistant to all the isolates. Seedling tests identified cvs Hunter and Turpin as carrying resistance effective against some WBV-1 pathotypes. A few isolates differentiating cv. Hunter from cv. Clement (WBR-1) have been detected in previous years, although they respond similarly to the majority of isolates. Cultivar Encore which expressed resistance of a mainly mixed type, at 25°C in seedling tests to some WBV-1 isolates, is also placed in this group.

Group 2: Cultivars displayed quantitative differences in susceptibility to the isolates, all of which were identified in seedling tests as carrying the corresponding virulence factor WBV-2. Infection levels were much lower on these cultivars within the nursery inoculated with isolate WBRS-93-56/1. Cultivars Hobbit and Norman, which carry additional resistance to Fundin (Clifford *et al.*, 1982), were again more resistant within each nursery.

Group 3: Disease levels were much higher on cv. Sappo (WBR-3) in the nurseries inoculated with isolates WBRS-91-65/1 and WBRS-93-80/1, although only the former was identified as carrying the corresponding virulence factor in seedling tests.

Group 4: Isolates WBRS-91-65/1 and WBRS-93-80/1 clearly differentiated the resistances of cvs Halberd and Sappo.

Group 5: Cultivar Huntsman (WBR-5) was highly susceptible to all 4 isolates as were cvs Mercia and Armada. Isolates differentiating cvs Huntsman and Mercia have been identified in previous years.

Group 6: The adult plant resistance of cvs Gamin (WBR-6) and Dynamo were ineffective against isolate WBRS-93-87/1 with isolate WBRS-93-80/1 also infecting them albeit at lower levels. Cultivar Virtue was also susceptible to the former isolate but previous tests have identified its resistance to be different to that of cv. Gamin.

Group 7: Similarities in their seedling reactions to the 1994 isolates (see above) indicate that the spring wheat cv. Chablis carries resistance factor WBR-7 in common with cvs Sterna and Sabre. Cultivar Shiraz, which was only susceptible at 25°C in the same tests to isolates carrying virulence factor WBV-7, is grouped with these cultivars.

Group 8: The low temperature resistance present in cv. Avans was effective against isolates WBRS-93-56 and WBRS-93-87 but ineffective against WBRS-93-80 in seedling tests. It displayed a similar response to the corresponding sub-isolates in the 1994 field nurseries.

Group 9: These cultivars are grouped on the basis of similarities in their responses to the isolates in the 1994 field isolation nurseries. Cultivar Buster had reacted similarly to cv. Ranger (WBR-8) in the 1993 field tests suggesting that they may share a common resistance. This year's field results indicate that this is not so with cv. Buster being highly susceptible to WBRS-93-87/1.

Group 10: The adult plant resistance of cv. Spark was overcome only by isolate WBRS-93-87/1 which was also virulent on cv. Hereward. These cultivars had been susceptible to WBRS-93-87 isolate in controlled environment tests, in which they had also been susceptible to isolate WBRS-93-56 (Jones and Clifford, 1994) but which failed to infect them in these field tests. Cultivar Consort reacted similarly to cv. Spark to the isolates, these 2 cultivars showing higher levels of disease than cv. Hereward to isolates carrying the corresponding virulence. It appears that these 3 cultivars carry a specific resistance in common which is effective only at later growth stages.

Group 10a: Data from last year's field test suggested that cvs Soissons and Pastiche carry the same resistance factor, with the latter being infected at lower levels by virulent pathotypes. They carry a low temperature resistance which was effective in controlled environment test (Jones and Clifford, 1994) against the 4 isolates introduced into the 1994 field nurseries but which was ineffective to WBRS-93-87/1 in the field.

Group 11: These are grouped together on the basis of their seedling responses to the 1994 isolates. Cultivars Hussar and Brigadier were susceptible to isolate WBR-93-56 in previous adult plant glasshouse tests but were resistant to the sub-culture WBR-93-56/1 in the 1994 field isolation nurseries.

Group 11a: 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. Some plants within the plots of cv. Andante showed infection levels of up to 25% in two of the nurseries, suggesting a mixed seed lot.

CONTROLLED ENVIRONMENT TESTS

Controlled environment tests during 1993/1994 enabled the resistances of some currently grown and NIAB Recommended List wheats to be classified. They also identified virulence to cultivars which had previously expressed high levels of resistance in the field. One isolate, WBRS-93-56, which was virulent on cultivars such as Hussar, Brigadier, Hunter, Hereward and Spark in these tests failed to infect them in field nurseries at IGER, Aberystwyth, or in spreader bed tests at the NIAB, Cambridge, in 1994. Virulencies identified in some of the other isolates tested also failed to be confirmed in the field, although virulence to cv. Slejpner (WBRS-93-56) and to cvs Hereward and Spark (WBRS-93-87) identified in the controlled environment tests was confirmed in the field isolation nurseries.

Tests with 1994 Isolates

Seventeen winter and 5 spring wheat cultivars were grown in spore-proofed conditions to the flowering stage of growth. The cultivars were inoculated with one or other of the following isolates:

Isolate	Origin
WBRS-94-2 (WBV-6)	cv. Slejpner, Southend Farm, Herts
WBRS-94-50 (WBV-1,2,6)	cv. Flame, Barroway Drove, Norfolk

The virulence factors given for the isolates were identified from seedling tests. Isolate WBRS-94-50 was cultured from infected leaves sampled from cv. Flame at a site in Norfolk where it showed infection levels of up to 25%. This cultivar has previously shown high levels of resistance in field isolation nurseries and has a NIAB disease rating of 8. Two replicates of each cultivar were incubated under each of the following regimes following inoculation:

1. 10°C constant and 12 h photoperiod
2. 25°C constant and 16 h photoperiod

Results

These are given in Table 8. Isolate/cultivar interactions were classified on the standard 0-4 scale as detailed for the glasshouse seedling tests. Assessments of reaction type were made on the responses of the last-formed (flag) leaf, ten days post-inoculation at 25°C and 26 days post-inoculation at 10°C. Where differences occurred between replicates, both reactions are given.

Cultivar Armada, which has no known resistance, was susceptible to both of the isolates. The other cultivars, which had been selected on the basis of the high levels of resistance shown in other tests, were all resistant, except for cv. Soissons, to isolate WBRS-94-2. This isolate, which had been cultured from an infected leaf sample of cv. Slejpner, failed to infect this cultivar in these tests.

In contrast, isolate WBRS-94-50 was widely virulent, overcoming the resistances of the winter wheat cultivars. Only cvs Cadenza and Andante expressed resistance, with the former being resistant at 10°C only. Cultivar Andante displayed a resistant reaction of a mixed type, although one replicate at the lower temperature was susceptible. The resistances of the spring wheat cultivars remained effective. There was no clear indication of temperature affecting the majority of host:pathogen relationships in these tests, with the exception of cv. Cadenza which expressed resistance at the low temperature regime only to isolate WBRS-94-50.

Isolate WBRS-94-50 will be tested in field isolation nurseries in 1995. Should it induce the same host cultivar responses in the field, then the existence of a pathotype carrying such a wide range of virulences will be of concern, especially if it becomes widespread. Isolates carrying virulence to some of these 'resistant' varieties have been identified previously in controlled climate tests but failed to infect them in the field. This isolate, as mentioned previously, was cultured from leaves sampled from a heavily infected field plot of a cultivar which has shown high levels of resistance.

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. (1992). Brown rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1991 Annual Report, pp.19-23.

Jones, E.R.L. and Clifford, B.C. (1994). Brown rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1993 Annual Report, pp.20-35.

Table 7. Percentage infection of winter and spring* wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1994

Cultivar (NIAB rating)		Group	WBR factor	WBRS-93-56/1	WBRS-91-65/1	WBRS-93-87/1	WBRS-93-80/1
Clement		1	1	30	0.1	15	29
Haven	(3)	1a	1+	24	1	20	23
Beaver	(4)		1+	14	0.2	12	21
Apollo			1+	23	0.4	22	24
Admiral	(5)		1+	12	0.1	5	11
Rialto	(3)	1b		27	Trace	26	29
Slejpner		1c	1+APR	12	Trace	1	18
Zodiac		1d	1+APR	3	0	0.2 MS	0.1 MR
Hunter	(8)		1+APR+OR	Trace	0	0	0
Turpin			1+APR+OR	0.2 R	0	0.2 R	0
Encore	(8)		1+APR+OR	0.2 MR	0	0	0.2 R
Fundin		2	2	34	7	43	39
Hobbit			2+	16	2	23	17
Norman			2+	6	1	15	8
Sappo*		3	3	2	22	5	38
Halberd*		4	4	0	0	0.3	4
Huntsman		5	5(APR)	42	30	39	29
Mercia	(6)		APR	32	28	33	29
Armada			0	40	31	36	32
Gamin		6	6(APR)	1	0	15	5
Dynamo	(6)		APR	2	0	18	2
Virtue			APR	4	0	25	1 MR
Sterna		7	7	0	0	Trace R	Trace
Sabre			7	0	0	Trace R	0
Chablis*	(9)		7?	0	Trace	0	0
Shiraz*	(9)			0	0	0	0
Ranger		8	8(APR)	Trace	Trace	0.4	7
Avans*	(3)		OR?	0	0	0	13 MS

Table 7. (continued)

Cultivar (NIAB rating)	Group	WBR factor	WBRS-93-56/1	WBRS-91-65/1	WBRS-93-87/1	WBRS-93-80/1
Avalon	9	9(APR)	7	0	38	10
Buster (3)		APR	6	Trace	42	10
Riband (4)			14	0.6	24	12
Tonic* (3)			11	2	14	14
Scamp*			7	1	8	13
Alexandria* (3)		APR	2	0	5	12
Spark (6)	10	APR	1	0	20	2
Hereward (8)		APR	Trace	0	10	0.1 R
Consort (6)		APR	0.5 MS	0	21	0.2 MR
Pastiche	10a	APR	Trace	0	5	Trace
Soissons (3)		APR	0.3	0	23	0.2
Beaufort	11	OR?	0.2 R	0	Trace R	Trace R
Brigadier (8)		OR?	1 R	0	0.3 R	1 MR
Hussar (8)		OR?	Trace	0	0.1 MR	0.5 MR
Cadenza (7)	11a		0.2 R	0	7 MS	0.1 MR
Andante†			0†	Trace	0.5 MR	0†
Estica		APR	2	0	0.2 MS	0.1 MR
Torfrida		APR	Trace R	0	2 MR	Trace R
Genesis (8)		APR	0.1 R	0	0.2 R	0
Flame (8)			0	0	1 MR	0.2
Prophet			0	0	0	0
Lynx			0	0	0	0
Axona* (9)		APR	0	0	0	0.3 R
Canon* (6)		APR+OR	0	0	0	0.3 R
Baldus* (7)		APR+OR	0	0	0	0
Promessa* (9)		OR	0	0	0	0

Winter cvs: Mean of 3 replicates, 3 assessment dates   Spring cvs: Mean of 4 replicates, final assessment date
All reaction types susceptible unless stated.
R = resistant; MR = mixed resistant; MS = mixed susceptible; APR = adult plant resistance; OR = overall resistance.
( ) NIAB rating: 1 = susceptible; 9 = resistant; † Mixed: some plants showed infection levels of 25%

Table 8 Reactions of winter and spring* wheat cultivars (adult plants) to specific isolates of *P. recondita* at 10°C and 25°C

Isolate	WBRS-94-2 (WBV-6)		WBRS-94-50 (WBV-1,2,6)	
Incubation Temperature °C				
Cultivar	10	25	10	25
Armada	S	S	S	S
Soissons	MR/MS	S	S	S
Buster	MR	MR	S	S
Slejpner	R	MR	S	S
Zodiac	R	MR	MS	S
Hunter	R	R	MS/S[+]	S
Estica	R	R	S	S
Flame	R	R	S	S
Genesis	R	MR	S	S
Lynx	R	R	S	S
Spark	R	R	S	S
Torfrida	MR	R	S	S
Prophet	R	MR	MS	MS
Brigadier	R	R	MS	S
Hussar	R	R	MS/S[+]	MS
Cadenza	R	MR	MR	S
Andante	R	R/MR	MS/MR	MR
Shiraz*	R	R	R	R
Chablis*	R	R	MR	MR
Axona*	R	R	R	MR
Avans*	R	MR	R	MR
Promessa*	R	R	R	R

[†] Reaction assessed on flag leaf - 2

Reaction type assessed on 2 replicates. Both responses given where replicates differ (-/-)

S = susceptible; R = resistant.

MS - mixed susceptible; MR = mixed resistant.

BROWN RUST OF WHEAT ADULT PLANT TESTS AT NIAB

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Nine spreader beds of winter wheat were inoculated with different isolates of wheat brown rust. Five of the beds were part of the Recommended List testing programme, funded by the Home-Grown Cereals Authority, and were inoculated with those isolates used in the testing programmes in 1992 and 1993 (Mitchell 1993, 1994) with the addition of WBRS-93-56. The remaining four isolates were obtained from IGER, Aberystwyth, collected as part of the UKCPVS wheat brown rust survey in 1993. Details of the isolates are given in Table 1, and the results of the tests are summarised in Table 2.

Table 1. Details of isolates of wheat brown rust used in adult plant tests at NIAB in 1994.

Isolate	Year of sampling	Source cultivar	Location
Isolates used in Recommended List testing programme			
WBRS-87-7	1987	Unknown	Unknown
WBRS-90-9	1990	Avalon	Spalding, Lincolnshire
WBRS-91-65	1991	Pastiche	Grantchester, Cambridgeshire
WBRS-91-67	1991	Virtue	Trumpington, Cambridgeshire
WBRS-93-56	1993	Hunter	Kent
Other isolates			
WBRS-93-68	1993	Buster	Long Sutton, Lincolnshire
WBRS-93-70	1993	Pastiche	Southampton, Hampshire
WBRS-93-82	1993	Soissons	Long Sutton, Lincolnshire
WBRS-93-84	1993	Buster	Bristol, Avon

The results for isolates used in previous years were generally as expected, although compared to 1992 and 1993 infection was lower on Beaver and Haven, and higher on Mercia and Riband. The tests confirmed that WBRS-91-65 has virulence for Soissons and Pastiche, and that WBRS-91-67 has virulence for Buster and Virtue.

In adult plant tests in controlled environment rooms (Jones & Clifford 1994), WBRS-93-56 was able to infect Brigadier, Hunter and Hussar, the first evidence of virulence for these cultivars. In these tests in the field WBRS-93-56 gave a very low level of infection on Brigadier and Hunter late in the season, and did not infect Hussar, but gave greater infection on Slejpner than any other isolate.

The results for other isolates sampled in 1993 suggest that changes in the wheat brown rust population first noticed in 1991 are now widespread, namely virulence for Pastiche, Soissons, Virtue and Buster. In general all isolates giving a high level of infection on Pastiche also gave a high level of infection on Soissons, and similarly isolates giving a high level of infection on Virtue gave a high level of infection on Buster.

WBRS-93-84 gave a very high level of infection on Buster and Virtue, and also on Mercia and

Riband. It also gave low but significant infection on Andante, Flame and Lynx, which have previously been highly resistant to brown rust, and more infection than previously recorded on Hereward and Consort.

Table 2. Reactions of winter wheat cultivars to infection with nine isolates of brown rust in spreader beds at NIAB in 1994.

	% Infection with brown rust *								
Cultivar	87-7	90-9	91-65	91-67	93-56	93-68	93-70	93-82	93-84
Beaver	8	8	0.2	10	25	7	0.8	16	4
Brigadier	0	0	0	0	0.2	0	0	0.2	0
Hussar	0	0.2	0	0	0	0	0	0	0
Mercia	15	21.2	1	15	21	26	3	23	31
Riband	9	7	24	13	28	3	22	20	30
Admiral	5	8	20	13	16	5	12	18	3
Genesis	0	0	0	0	0.8	0	0	0	0.2
Haven	13	12	1	25	23	9	0.3	12	8
Hereward	0	0.8	0	0.2	0	0.8	0.5	3	6
Hunter	0	0	0	0	0.8	0	0	0	0
Spark	0	0	0	0.2	4	0	0	3	9
Cadenza	0.2	0	0	0.2	2	0	0	0.8	0.2
Zodiac	0	2	0	0	6	2	0	0	0
Andante	0	0	0	0	0	0	0	0	3
Buster	2	0.8	0	16	11	1	6	9	38
Flame	0	0	0	0	1	0	0	0.2	5
Lynx	0	0	0	0	0	0	0	0	3
Rialto	15	11	0.2	20	32	6	2	21	6
Prophet	0	0	0	0	0	0	0	0	0.2
Soissons	7	10	22	10	5	13	18	1	0.3
Encore	0	0	0	0	0	0	0	0	0
Consort	0	0	0	3	2	0	0.7	4	13
Beaufort	0	0	0	0	0.2	0	0	0	0
Dynamo	0.3	0.2	0	0	4	0	0	1	10
Turpin	0	0	0	0	2	0	0	0	0.2
Slejpner	0.5	1	0	0	16	0	0.2	0	0.2
Pastiche	3	7	16	6	4	4	13	2	0
Virtue	0	0	0	0.8	6	0	0.3	4	18
Avalon	2	7	0	8	16	0.8	1	6	24

* Mean of two replicates assessed three times

Jones, E. R. L. & B. C. Clifford (1994). Brown rust of wheat. *U.K. Cereal Pathogen Virulence Survey Annual Report*, pp. 20-35.

Mitchell, A. G. (1993). Brown rust of wheat adult plant tests at NIAB. *U.K. Cereal Pathogen Virulence Survey Annual Report*, pp. 24-25.

Mitchell, A. G. (1994). Brown rust of wheat adult plant tests at NIAB. *U.K. Cereal Pathogen Virulence Survey Annual Report*, pp. 36-37.

MILDEW OF BARLEY

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Virulences corresponding to all widely used specific resistances were recorded at high frequencies. Virulence for *mlo* was not detected, although increasing reliance is being placed on this resistance in spring barley. The barley mildew population has retained a high level of complexity, similar to that seen in recent years, which continues to reduce the opportunities for varietal diversification.

INTRODUCTION

The principal aim of the virulence survey of barley powdery mildew is to monitor changes in the frequencies of virulence factors and combinations of virulence factors used in commercial cultivars. Secondary aims are to determine the specific resistance of new cultivars, and to use the information on virulence frequencies to compile the variety diversification scheme.

METHODS

Single colony isolates of barley powdery mildew were derived from samples of infected leaves, mostly from Recommended List trials. Random samples of airborne spores were made 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 9 locations:

Bridgets, Hampshire	17	isolates	Cockle Park, Northumberland	10	isolates
Stebbing, Essex	8		Dundee, Scotland	81	
NIAB, Cambridge	75		Inverness, Scotland	4	
Clwyd, Wales	12		Aberdeen, Scotland	12	
Headley Hall, Yorkshire	64		Total	283	isolates

The source cultivars were:

<u>Winter cultivars</u>

Halcyon	2	isolates	Target	6	isolates	Sunrise	9	isolates
Hanna	12		Melanie	7		Tempo	10	
Bronze	2		Fanfare	14		Firefly	5	
Intro	2		Willow	2		Fighter	5	
Linnet	9		Puffin	4		Manitou	2	
Pastoral	4		Epic	4		Pipkin	5	
Sprite	2		Finch	2		Gaelic	8	

<u>Spring cultivars</u>

G. Promise	81	isolates	Felicie	6	isolates	Juno	2	isolates
Cooper	7		Alexis	1		Camargue	11	

Chad	2	isolates	Chariot	1	isolates	Tyne	11	isolates
Brewster	12		Derkado	1		Optic	10	
Cork	16		Hart	2		Amber	9	
Delibes	9		Heron	1		Riviera	5	

A further 18 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. Virulence was determined based on the infection types of Moseman *et al.* (1965). The nomenclature for resistance and virulence, based on the gene and allele designations, proposed by Boesen *et al.*(in press) has been used in this report. The corresponding BMR and BMV codes are also given.

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

Cultivar	Resistance gene	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	*Mlk*	6a
Porter	*Mla7*	6b
Lotta	*Ml(Ab)*	6c
Triumph	*Mla7, Ml(Ab)*	6b, 6c
Tyra	*Mla1*	7
Roland	*Mla9*	8
Simon	*Mlk, Mla9*	6a, 8
Apex	*mlo*	9
Digger	*Mla13*	10a
Ricardo	*Mla3*	11

RESULTS

Virulence

Frequencies of barley mildew virulences corresponding to the resistance genes in the differential cultivars, excluding *mlo*, are given in Table 2. Results are also given for non-corresponding virulence, where those virulences in individual isolates which correspond to the resistance in the host cultivar have been excluded. This gives some indication of the influence of host resistance on the virulence frequencies.

Virulences corresponding to resistances which have been widely used for a number of years were recorded at very high frequencies, as in previous years. Virulences *Va6* (BMV3), *VLa* (BMV4), *Va1* (BMV7), *Va9* (BMV8), and *Va13* (BMV10), which correspond to less widely used resistances, were recorded at frequencies of 10 to 50%. *Va3* (BMV11), which has not been used in commercial cultivars in the UK, was detected at a very low frequency in 1994 and showed no increase compared to 1993. Eight isolates were from cultivars with *mlo* (BMR9) resistance, but none were virulent on the *mlo* differential cultivar or their source cultivar.

There were small changes in the frequency of some virulences compared to 1993, probably due to changes in the number of cultivars with the corresponding resistance in trials or changes in commercial popularity. The frequency of *Va6* (BMV3) in the leaf sample was lower in 1994, and *Va7* (BMV6b) and *Va13* were recorded at lower frequencies compared to 1993 when all the data from the leaf sample was considered. *Va1* was recorded at a slightly higher frequency in all samples.

Table 2. Virulence frequencies in single colony isolates of barley mildew formed 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	80	87	80	84	68
Vra	1b	100	100	99	100	98
Vg	2a	98	97	93	96	81
V(CP)	2b	92	91	87	87	73
Va6	3	40	35	24	25	10
VLa	4	33	29	16	17	21
Va12	5	72	78	62	72	41
Vk	6a	72	68	66	73	78
Va7	6b	63	69	80	78	65
V(Ab)	6c	72	71	83	81	60
Va1	7	29	22	13	19	19
Va9	8	39	27	23	24	40
Va13	10	42	28	43	28	76
Va3	11	1	1	1	0	0
Number of isolates		283		93	100	63

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

Results of the barley mildew surveys carried out from 1990 to 1994 are summarised in Table 3. The frequencies of most virulences have been very stable over this period. The frequency of *Va1* increased in 1993 and 1994, probably as cultivars with the corresponding resistance, such as Chad, Brewster and Cooper have become more widely grown. The frequencies of

Va9 and *Va13* increased from 1990 to 1991, but have remained steady since. Cultivars with the corresponding resistances were increasing in popularity up until about 1990, but have not increased greatly since.

Table 3. Virulence frequencies in barley mildew, 1990 to 1994.

Virulence gene	Virulence factor	Virulence frequency (%) * 1990	1991	1992	1993	1994
Vh	1a	-	-	78	78	79
Vra	1b	-	99	100	100	99
Vg	2a	-	99	99	96	95
V(CP)	2b	-	96	98	92	88
Va6	3	15	23	31	35	31
VLa	4	29	36	24	22	25
Va12	5	64	61	73	72	67
Vk	6a	71	80	77	75	72
Va7	6b	74	78	78	76	69
V(Ab)	6c	62	64	72	76	74
Va1	7	14	15	13	18	23
Va9	8	16	28	26	29	34
Va13	10	31	43	42	38	43
Va3	11	-	-	-	1	<1
Number of isolates		314	780	462	628	539

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

\- No data

Complexity of isolates

The number of virulences carried by isolates in each sample is shown in Table 4. Almost all isolates in the leaf sample and the March random sample of airborne spores carried 6 or more virulences, and in the other two samples most isolates carried 5 or more virulences. There is some indication that the leaf sample is more complex than the random samples of airborne spores, particularly the October sample. This difference was also seen in 1992 but not in 1993. All of the samples showed a greater complexity than was observed in 1993, but were similar to that seen in the 1992 survey.

Frequencies of the most common pathotypes

The frequencies of the most common pathotypes in the samples made in 1994 are given in Table 5. Other pathotypes were recorded only one or two times in each sample. Most of these pathotypes have been common in the barley mildew population for at least five years, although generally at higher frequencies than in 1994.

Table 4. Number of virulences carried by isolates of barley mildew in 1994. *

No. of virulence factors	Frequency of isolates with each number of virulences			
	Leaf samples	Random samples of airborne spores: March	June	October
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	1	5
5	3	3	4	11
6	10	10	6	14
7	20	32	27	25
8	22	35	34	17
9	20	10	14	14
10	14	9	12	11
11	6	1	1	0
12	4	0	0	2
13	0	0	0	0
No. of isolates	283	93	100	63

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

Table 5. Frequencies of the most common barley mildew pathotypes identified in 1994, defined by *Vh, Vra, Vg, V(CP), Va6, VLa, Va12, Vk, Va7, V(Ab), Va1, Va9* and *Va13*.

Pathotypes *	Frequency of pathotypes (%): Leaf sample	Samples of airborne spores: March	June	October
Va12 Va7 V(Ab)	2	14	14	2
Va12 Vk Va7 V(Ab)	3	11	13	2
Va6 Va12 Va7 V(Ab)	1	4	1	0
Va6 Va12 Vk Va7 V(Ab)	2	3	3	0
Va6 Va12 Va7 V(Ab) Va1	4	1	0	0
Va12 Vk Va7 V(Ab) Va1	3	1	3	0
Vk Va7 V(Ab) Va13	1	9	2	2
Va12 Vk Va7 V(Ab) Va13	1	0	3	6
Vk Va7 Va9 Va13	1	2	0	0
Vk Va7 V(Ab) Va9 Va13	0	3	0	3
Total number of pathotypes	144	50	57	51
Total number of isolates	283	93	100	63

* 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 in UK Recommended List candidates tested in 1994 are given in Table 6. No new resistances or combinations of resistances were identified.

Table 6. Specific resistance genes of barley cultivars.

None (BMR0)
Halcyon (W)
Hanna (W)

Mlra (BMR1b)
Bronze (W)
Chestnut (W)
Intro (W)
Linnet (W)
Pastoral (W)
Swift (W)
Sprite (W)

Mlh, Mlra (BMR1a,1b)
Angora (W)
Melanie (W)
Target (W)

Mlra, Mlg (BMR1b,2a)
Fanfare (W)

Mla9 (BMR8)
Manitou (W)

mlo (BMR9)
Alexis (S)
Chariot (S)
Dandy (S)
Derkado (S)
Hart (S)
Heron (S)
Juno (S)

Mla13 (BMR10)
Camargue (S)
Pipkin (W)

Mlra, Mla6 (BMR1b,3)
Gaelic (W)

Mlh, Mlra, Mlg, Ml(CP), Mla6 (BMR1,2,3)
Epic (W)
Finch (W)
Sunrise (W)
Tempo (W)

Mlh, Mla12 (BMR1a,5)
Willow (W)

Mlh, Mlra, Mlg, Ml(CP), Mla12 (BMR1,2,5)
Puffin (not *Mlra*)(W)
Firefly (W)

Mlh, Mlra, Mla7 (BMR1,6b)
Marinka (W)

Mlg, Ml(CP), Mla9 (BMR2,8)
Felicie (S)

Mlg, Ml(CP), Ml(Ab) (BMR2,6c)
Fighter (W)

Ml(Ab) (BMR6c)
Optic (+?) (S)

Ml(La), Mla13 (BMR4,10)
Tyne (S)

Mla12, Ml(Ab) (BMR5,6c)
Blenheim (S)
Prisma (S)

Ml(Ab), Mla1 (BMR6c,7)
Brewster (S)
Chad (S)
Cork (S)
Delibes (S)

MlLa, Mla1 (BMR4,7)
Cooper (S)

Ml(Ab), Mla9 (BMR6c,8)
Nomad (S)

Unknown
Amber (S)
Goldie (S)
Riviera (S)

(W) winter cultivar, (S) spring cultivar

Tests for sensitivity to fenpropimorph

A sample of 68 isolates was selected from those collected in 1994 and tested for sensitivity to fenpropimorph. Segments were cut from seedlings of Golden Promise sprayed with various rates of fenpropimorph 24 hours previously, and inoculated with conidia using a settling tower. After incubation at 15°C for 10 days assessments were carried out using a 0 - 4 scale for leaf area infected with mildew. The tests were carried out in two batches. The same five control isolates used in 1991 and 1993 and three isolates with reduced sensitivity from the 1993 test were included in each batch. The two tests cannot be compared directly, but the isolates can be compared with the controls in the same batch.

Table 7 shows assessments of mildew for each rate of fenpropimorph as the proportion of infection on untreated seedlings. The insensitive controls gave more infection on the three highest rates in the first test, although both batches gave similar results using the lowest dose. The sensitive controls were similar in both batches. The least sensitive isolates in the first batch were those from Aberdeen, although these were more sensitive than the insensitive controls. In batch 2, most of the isolates were similar to, or more sensitive than the controls. However, one isolate from Bridgets was less sensitive than the control isolates.

Table 7. Sensitivity of barley mildew isolates collected in 1994 to fenpropimorph

		Growth as % of growth on untreated plants			
		Rate of fenpropimorph as proportion of field rate			
Location	No. of isolates	0.01	0.02	0.05	0.1
Batch 1					
Airborne sample, June	10	31	6	0	0
Cambridge	6	50	23	1	0
SCRI, Dundee	10	69	21	1	0
Aberdeen	6	82	38	0	0
Sensitive controls	3	1	0	0	0
Insensitive controls	5	70	56	19	2
Batch 2					
Airborne sample, March	10	45	11	0	0
Airborne sample, Oct.	10	46	9	0	0
Cambridge	4	50	21	0	0
Bridgets, Hants	2	58	31	6	1
SCRI, Dundee	10	54	25	0	0
Sensitive controls	3	0	0	0	0
Insensitive controls	5	70	23	0	0

The results from 1994 are compared with those from 1991 and 1993 in Table 8. The same control isolates were used in each year, but the amount of infection varies considerably. In 1991, the sensitive controls gave more infection on the lowest rates than in 1993 and 1994, and this must be taken into account when comparing the isolates tested in different years. The insensitive controls also varied, giving more infection in 1991 and least in 1993.

Table 8. Sensitivity of isolates collected in 1991, 1993 and 1994 and the control isolates to fenpropimorph

			Growth as % of growth on untreated leaves			
			Rate of fenpropimorph as proportion of field rate			
Year	Isolates	No. of isolates	0.01	0.02	0.05	0.1
1991	sample	20	32	12	6	0
	sens. controls	3	41	3	0	0
	insens. controls	2	103	100	63	24
1993	sample	49	24	13	2	0
	sens. controls	3	0	0	0	0
	insens. controls	2	32	22	1	0
1994	sample	68	54	20	1	0
	sens. controls	3	0	0	0	0
	insens. controls	2	73	49	11	4

Although more isolates were tested in 1994 compared to 1991 and 1993 the 68 isolates tested still represent only a small part of the mildew population. Thus, from the results obtained in 1994, there does not appear to have been any large shift in the barley mildew population towards reduced sensitivity to fenpropimorph since 1991. However, as varying levels of sensitivity were detected, the potential for an increase in the frequency of less sensitive isolates such as the one from Bridgets should be acknowledged.

CONCLUSIONS

Virulences corresponding to all widely used specific resistances were recorded at high frequencies. Virulence for *mlo* was not detected, although increasing reliance is being placed on this resistance in spring barley. In 1994 *mlo* cultivars made up about 75% of the spring barley seed crop in England and Wales. There was no indication of a further shift in sensitivity to fenpropimorph.

REFERENCES

Boesen, B., M. S. Hovmøller & J. H. Jørgensen (in press). Designations of barley and wheat powdery mildew resistance and virulence in Europe. *Proceedings of the 3rd. Cereal Mildew Workshop, 1994.*

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

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

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

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

Moseman, J. G., R. C. F. Macer & L. W. Greeley (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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For many of the single resistance genes and combinations thereof there was little significant difference from previous years. However, the large increase in *Va1* (BMV 7) noted in 1993, was not repeated in the present season. There was an increase in frequency for the combined virulence *VLa, Va13* (BMV 4 + 10) and a continuation in decline of *VLa, Vk* (BMV 4 + 6a). The level of resistance to Baytan seed-treatment continues to decline. However, it is clear from a comparison with an "herbarium mildew" that the current level is still considerably greater than that obtaining in the 1970s.

Thirty-four 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 the testing of virulences of the isolates are shown in Table 3, while the most commonly sown barley cultivars in N. Ireland in the previous season, 1993/4, are shown in Table 2.

Table 1. Sources of mildew isolates tested in 1994

Resistance gene(s)	Isolate source	No. isolates
mlo	Chariot	7
	Derkado	2
MlLa, Mla13	Tyne	8
Ml(Ab), Mla1	Chad	17

Table 2. Percentage use of barley cultivars in N. Ireland (1993/94)

Spring cultivars (resistance genes)		Winter cultivars (resistance genes)	
Chariot (*mlo*)	42	Pastoral (*Mlra*)	42
Dandy (*mlo*)	21	Fighter (*?, Mlra*)	35
Chad (*Ml(Ab), Mla1*)	19		

In accord with the recommendations made at the COST 817 meeting in Zurich, resistance gene designations will be used this year as well as the old resistance group codes, although a table of comparisons is provided (Table 3). The frequencies (Table 4) of the single major genes *VLa* (BMV 4), *Va12* (BMV 5) and *Va9* (BMV 8) were almost identical to those of the previous year. Of the other two single genes, *Va1* (BMV 7) and *Va13* (BMV 10), *Va1* was lower and *Va13* higher than the previous year. Whether either of these differences is of significance is dubious as similar frequencies had been observed in the recent past. The decrease in *Va1* compared with the previous year does however throw into doubt the effect of the current popularity of *cv.* Chad which was postulated last year. One consistent feature is the relatively low frequency of *Va9* (BMV 8) over the years. Frequencies of the combined virulences were generally within the range of variation noted in previous years with the exception of *VLa, Vk* (BMV 4 + 6a) which appears to be on a downward curve and *VLa, Va13* (BMV 4 + 10) which appears to be increasing. There were still no mildew pustules on the differential cultivar Atem (*MlLa, mlo*; BMR 4 + 9) even though Chariot and Dandy (both *mlo*) comprised over 60% of the spring barley area.

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

Cultivar	Resistance gene	BMR group	European code
Golden Promise	none	0	0
Zephyr	*Mlg, Ml(CP)*	2	We
Midas	*Mla6*	3	Sp
Goldspear	*Mla6, MlLa*	3 + 4	Sp, La
Varunda	*MlLa*	4	La
Egmont	*MlLa, Mla12*	4 + 5	La, Ar
Dram	*MlLa, Mlk*	4 + 6a	La, Kw
Klaxon	*MlLa, Mlk, Mla7*	4 + 6a + 6b	La, Kw, Ly
Atem	*MlLa, mlo*	4 + 9	Mlo
Tyne	*MlLa, Mla13*	4 + 10	La, Ru
Hassan	*Mla12*	5	Ar
Keg	*Mlk, Mla7*	6a + 6b	Kw, Ly
Triumph	*Mla7, Ml(Ab)*	6b + 6c	Ly, Ab
Delta	*Mla1*	7	A1
Leith	*Mla9*	8	MC
Digger	*Mla13*	10	Ru

Table 4. Frequencies of virulence alleles from isolates collected from barley crops from 1990 - 1994.

Virulence gene	BMV group	Frequency of virulence allelles (%) 1990	1991	1992	1993	1994
Vg, V(CP)	2	43	64	39	43	77
Va6, Va14	3	41	54	36	47	56
VLa	4	27	57	25	47	42
Va12	5	46	54	31	67	74
Vk, Va7	6a + 6b	48	57	31	37	38
Va7, V(Ab)	6b + 6c	33	71	36	47	59
Va1	7	20	14	14	40	22
Va9	8	27	30	28	30	29
Va6, Va14, VLa	3 + 4	67	39	36	30	50
VLa, Va12	4 + 5	27	50	47	30	53
VLa, Vk	4 + 6a	50	50	44	30	24
VLa, Vk, Va7	4 + 6a + 6b	59	41	44	27	38
corresponding to MlLa, mlo	4 + 9	0	0	0	0	0
VLa, Va13	4 + 10	n.a.	n.a.	3	0	11
Va13	10	14	46	25	27	37

Tests continued with Baytan seed-treatment. When the current year's results are combined with those from previous seasons (Fig. 1) there is a rather erratic response with time, with a peak in 1989 but an apparent levelling-off in resistance in recent years. A comparison was also included this year with two "herbarium mildews" obtained from Dr. Felsenstein of Weihenstephan in Germany. These isolates dated back to the 1970s, a period before triazole fungicides were used. There is quite a dramatic difference between the current relatively low incidence of resistance and the almost complete lack of it by the two German isolates.

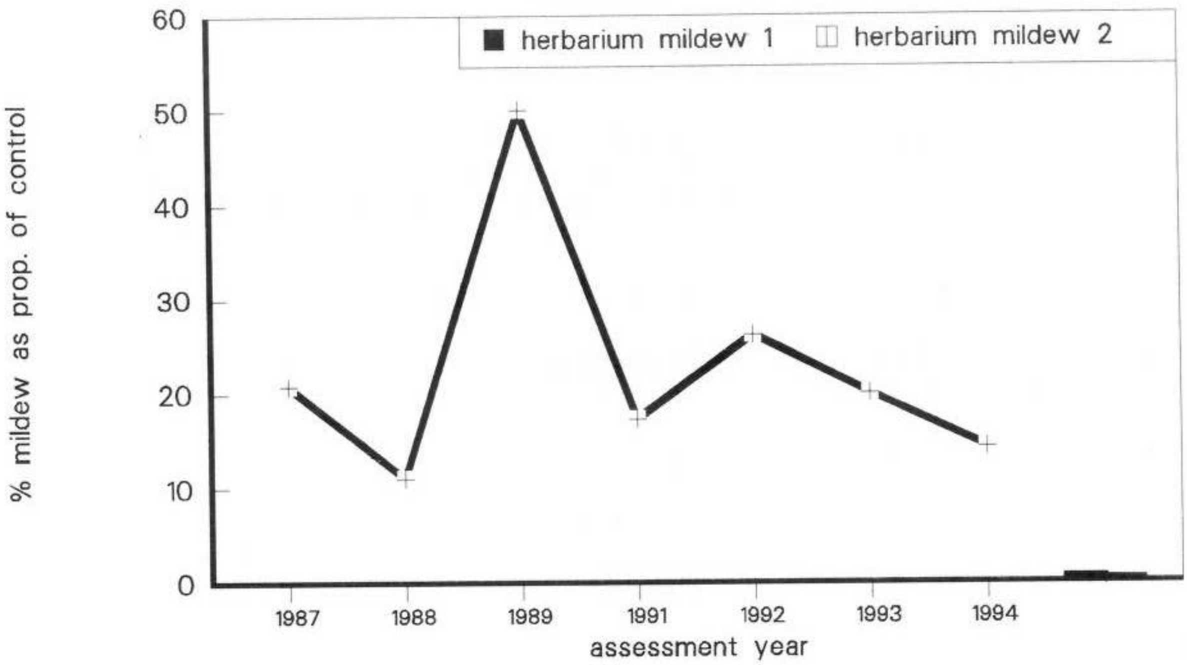

Fig. 1 Percentage of colonies of mildew growing on Baytan-treated seedlings (full recommended rate) as a proportion of those on untreated seedlings.

YELLOW RUST OF BARLEY

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Of the six samples received in 1994 only one established infection. This sample possessed the BYV 123. The other samples were received from the winter barley cultivars Intro (3), Ara (1) and a wild barley (1).

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 1994 isolate

Of the six samples received in 1994 only one established infection. This sample was received from the Scottish Crops Research Institute, Dundee from a winter barley breeding line. The other samples were received from the winter barley cultivars Intro (3), Ara (1) and a wild barley (1).

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

RESULTS

Virulence frequencies for 1979-1994 are shown in Table 2.

Table 2 Virulence factor frequency (%)

	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94
BYV 1	100	100	100	100	100	100	-	-	100	-	100	100	100	100	100	100
BYV 2	0	54	81	96	87	100	-	-	100	-	100	0	100	100	100	100
BYV 3/	-	-	-	-	17	86	-	-	22	-	75	0	0	0	0	100
Number of isolates	1	56	52	25	30	7	0	0	9	0	4	1	1	2	1	1

/ Not included in tests before 1983.

The 1994 isolate was virulent on the BYV 1 differentials Astrix and Atem, the BYV 2 differentials Bigo and Varunda and the BYV3 differential Triumph.

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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Six different, previously detected virulence combinations were identified from the 12 isolates tested.

GLASSHOUSE SEEDLING TESTS WITH 1993 ISOLATES

Fewer samples of barley brown rust were received in 1994 compared to recent years. The 24 samples were sent from the CSL/ADAS Cereal Disease Survey and were from a range of winter barleys. Isolates of *Puccinia hordei* Otth. were cultured from half of the samples and tested on the standard set of differential cultivars (Table 1.).

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

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

Results

The geographic and cultivar origins of the samples, virulence combinations identified and octal designations assigned to the 12 isolates are given in Table 2.

Table 2. Locations and cultivars from which rust isolates were cultured in 1994 with virulences for each sample.

Location	Cultivar	BBV factors	Octal designation
NIAB Region			
South East			
Kent	Marinka	1,2,3,4,5,6,8,9,10	1677
	Unknown	1,2,4,6,8,9,10	1653
Sussex	Pastoral	1,2,4,5,6,8,9,10	1673
Essex	Unknown	1,2,4,6,8,9,10	1653
Bedfordshire	Unknown	1,2,4,5,6,8,9,10	1673
Central			
Warwickshire	Target	1,2,3,4,6,8,9,10	1657
Humberside	Fighter	1,2,4,5,6,8,9,10	1673
South West			
Devon	Fighter	1,2,3,4,5,6,8,9,10	1677
	Manitou	1,2,3,4,5,6,8,9	677
Somerset	Unknown	1,2,4,5,6,8,9,10	1673
	Marinka, Pastoral	1,2,4,5,6,8,9	673

All virulence combinations identified from the 1994 isolates had been detected in previous seasons. The resistance of Cebada Capa (Pa_7) remains effective in the U.K.

RHYNCHOSPORIUM OF BARLEY

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Virulence to cv. Osiris (BBR-6) identified in 5 isolates was again combined with virulence to cv. La Mesita (BBR-5). Some isolates induced higher levels of infection on seedlings of cv. Digger than have been observed previously. Several winter barley cultivars displayed good levels of resistance in field isolation nurseries. Glasshouse adult plant tests identified the winter barley cv. Willow as carrying resistance factor 1 or 2.

SEEDLING TESTS WITH 1993 ISOLATES

Leaf samples infected with *Rhynchosporium* were received from 76 winter and 8 spring barley cultivars in 1994. Of these, 68 were collected from a wide range of cultivars at trial sites in four locations. The remaining samples were from the winter barley cvs Marinka (9), Manitou (4), Target (2) and Maris Otter. The geographic origins of the samples are given in Table 1.

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

Location	Number of samples
NIAB Region	
North East	
Udny, Grampian	19
Huntly, Grampian	7
Ellon, Grampian	1
Laurence Kirk, Grampian	1
Inverness, Highland	16
Dundee, Tayside	1
Cockle Park, Northumberland	1
Central	
Headley Hall, North Yorkshire	28
Burwarton, Shropshire	1
Essington, Staffordshire	1

Table 1. (continued)

Location	Number of samples
NIAB Region	
<u>South-east</u>	
Kent	1
East Sussex	1
Horsham, West Sussex	1
<u>South-west</u>	
Holsworthy, Devon	1
South Milton, Devon	1
Devon	1
Hereford and Worcester	1
Aberystwyth, Dyfed	1

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

Table 2. Differential test cultivars for *Rhynchosporium secalis*

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

Results

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). These virulence combinations gave a range from single virulence factors found in 2 isolates to the widely virulent BRV-1,2,3,4,5,6,7 (race octal 177) found in 4 isolates.

Table 3. Virulence factor combinations identified from the 1994 survey

No. of isolates	Differential cultivars in linear order							Race octal
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
44	1	0	0	1	1	1	1	117
8	0	0	0	1	1	1	1	17
4	1	0	0	1	1	0	0	114
4	1	1	1	1	1	1	1	177
3	1	0	1	1	1	1	1	137
1	1	0	1	1	1	0	0	134
1	1	1	1	1	1	0	0	174
1	0	0	1	0	0	0	0	20
1	0	0	0	0	1	0	0	4

1 = susceptible 0 = resistant

Virulence to cv. La Mesita (BRR-5) was detected in 10 isolates. Five of these also carried virulence to cv. Osiris (BRR-6) (Table 4). As in previous years, BRV-6 was only found in isolates also carrying BRV-5. Only one sample, RS-94-28 from Headley Hall, was received from cv. Pipkin (BRR-5) which derives its resistance from cv. La Mesita. Seedling tests on the isolate cultured from this sample confirmed that it carried only BRV-5, as it failed to infect any of the other standard differential cultivars. Four other samples from this site were shown to also carry virulence to cv. La Mesita (BBR-5) but in these it was combined with additional virulences in the more complex races octal 137 and 177. Race octal 177, also found in 3 samples from Scotland, is able to attack all of the standard differential cultivars.

Table 4. Origins of isolates identified as carrying BRV-5 or BRV-6

Isolate number	Cultivar	Origin	BRV-factors	Race octal
RS-94-24	Hanna	Headley Hall, N.Yorks	1,2,3,4,5,6,7	177
RS-94-42	Gaelic	Balspardon, Inverness	1,2,3,4,5,6,7	177
RS-94-70	Finch	Udny, Aberdeen	1,2,3,4,5,6,7	177
RS-94-73	Pastoral	Udny, Aberdeen	1,2,3,4,5,6,7	177
RS-94-2	Manitou	Ellon, Aberdeen	3,4,5,6,7	174
RS-94-23	Pastoral	Headley Hall, N.Yorks	1,2,3,4,5,7	137
RS-94-77	Juno	Headley Hall, N.Yorks	1,2,3,4,5,7	137
RS-94-81	Hart	Headley Hall, N.Yorks	1,2,3,4,5,7	137
RS-94-83	Manitou	Udny, Aberdeen	3,4,5,7	134
RS-94-28	Pipkin	Headley Hall, N.Yorks	5	20

The spring barley cv. Digger displayed higher levels of infection (5-10%) to some isolates than have been seen previously. The resistance of this cultivar, which has been included in seedling and adult plant tests over a number of years, has been very effective, although some isolates have induced infection levels of 2-5% in glasshouse seedling tests. 1994 isolates identified as being virulent on cv. Osiris (BRR-6) infected cv. Digger at these higher levels but some isolates lacking BRV-6 also induced infection levels of 5-10%.

Frequencies of virulences (Table 5) to cvs Armelle (BRR-1) and Astrix (BRR-2) continued to increase in 1994, and the frequency of isolates carrying virulence to cv. Pirate (BRR-7) also increased.

Table 5. Frequencies of individual virulences, 1988-1994

	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

ADULT PLANT TESTS IN ISOLATION NURSERIES

Thirty-three winter and 26 spring barley cultivars were sown in each of two nurseries in the 1993-1994 season. One nursery was artificially inoculated throughout the season with isolate RS-93-56 (race octal 174) which is widely virulent. The second nursery was grown alongside and received inoculum from a *Rhynchosporium* disease nursery used to screen barley material and which is infected naturally. Infected leaf samples were taken from the nursery during the season and the isolate cultured from these was identified as race octal 114 when tested on seedlings of the set of differential cultivars.

An additional nursery comprising the 26 spring barleys was grown at a site in Mylnfield, Scotland (Dr A. C. Newton). The cultivars in this nursery became infected with naturally-occurring pathotypes.

Results

Winter barleys: Good levels of leaf blotch built up on the susceptible cultivars in both IGER nurseries (Table 6), although it was slower developing in the artificially inoculated nursery. The cultivars displayed a range of quantitative responses within both nurseries with cultivar rankings between nurseries following a similar pattern with the exception of cv. Epic which was more highly infected within the naturally inoculated nursery. Cultivar Pipkin was again susceptible to an isolate which was not identified as carrying the corresponding virulence gene (BRV-5) in seedling tests (Jones and Clifford, 1982). Several of the winter barley cultivars displayed good levels of resistance.

Spring barleys: High levels of infection developed on the susceptible spring barleys (Table 7) grown within the naturally infected nurseries at IGER and SCRI. Levels of disease were too low to warrant assessment on the cultivars grown in the artificially inoculated nursery. Cultivar rankings within the naturally infected nurseries showed a similar pattern with the exception of cv. Optic which was the most susceptible cultivar at SCRI. The resistances of cvs Digger and Osiris (BRR-6) remained effective.

GLASSHOUSE TESTS

It is often difficult to achieve satisfactory levels of leaf blotch infection in field nurseries inoculated artificially with specific isolates of the pathogen largely because prolonged dry spells of weather result in moisture levels too low for spore germination. Also, being a splash-borne pathogen infection will not spread to new growth. When weather conditions are conducive to the development of infection, there is the problem of the nurseries becoming contaminated with naturally occurring inoculum. Because of these difficulties, it has been decided that in future, tests to study adult plant responses to specific isolates will be carried out under controlled conditions in the glasshouse. During 1994 a preliminary glasshouse study was carried out to evaluate the validity of the tests.

Twenty spring and 7 winter barleys were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were 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

These isolates were from a batch of cultures received from Dr Tom Locke (ADAS, Worcester) for virulence testing as part of a study on fungicide insensitivity. The 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. Assessments were made of the percentage area of the flag leaf infected. Results are given in Table 8. Seedlings of the cultivars were also inoculated with the same isolates and incubated under the same conditions as the adult plants. Seedlings were assessed as susceptible (S) or resistant (R).

Results

The majority of the cultivars tested were susceptible to the 3 isolates as seedlings and adult plants, although quantitative differences in infection levels were apparent. The spring barley cv. La Mesita (BRR-5) was resistant in seedling tests to isolates RS-93-33G and RS-93-1A but susceptible to isolate RS-93-52J. It also showed much higher levels of infection to the latter isolate in adult plant tests suggesting that, although it is susceptible at later growth stages to isolates which do not carry the corresponding virulence (BRV-5), it is more heavily infected by isolates which do. Only low levels of infection were observed on the flag leaves of cv. Osiris (BRR-6) inoculated with isolate RS-93-52J (race octal 164) whereas seedlings were susceptible to the same isolate.

The race-specific resistances of cvs Armelle (BRR-1) and Astrix (BRR-2) were confirmed. They were susceptible to isolate RS-93-1A (race octal 117) in seedling and adult plant tests but resistant to the two other isolates. The winter barley cv. Willow, which has been highly susceptible in field isolation nurseries and has a NIAB rating of 3 for resistance to *Rhynchosporium*, showed a similar pattern of responses to the isolates, suggesting that it also carries either BRR-1 or BRR-2.

Cultivar Manitou, which was highly resistant in the field isolation nurseries, was susceptible to races octal 4 and 164 in seedling tests but showed low levels of infection in the adult plant tests. It may have adult plant resistance. Isolate RS-93-1A (race octal 117) failed to infect cv. Manitou at the later growth stages and only induced low levels of infection in seedling tests. The resistance of cv. Digger remained effective.

REFERENCE

Jones, E.R.L. and Clifford, B.C. (1982). *Rhynchosporium* of barley. United Kingdom Cereal Pathogen Virulence Survey 1981 Annual Report, pp.61.64.

Table 6. Percent infection of winter barley cultivars in *Rhynchosporium* isolation nurseries in 1994

Cultivar (NIAB rating)		Naturally infected* (see text)	RS-93-56† (BRV-3,4,5,6,7)
Willow	(3)	30	20
Otter		20	29
Finch		19	22
Pipkin	(3)	18	11
Bronze		18	9
Intro	(5)	18	5
Gaelic	(5)	16	6
Epic	(6)	15	0.5
Igri		13	9
Puffin	(7)	13	5
Linnet	(6)	12	3
Surprise	(7)	12	7
Clarine		10	4
Tempo		9	6
Gaulois		8	3
Athene		7	7
Halcyon	(5)	7	3
Fighter	(6)	7	3
Pastoral	(7)	7	3
Fanfare	(8)	7	2
Melanie	(8)	6	2
Sprite	(8)	6	1
Gypsy		6	1
Astrix		5	2
Hoppel		5	0.4
Kira		4	2
Torrent		4	1
Pirate		3	0.3
Target	(8)	2	0.3
Marinka		2	0.2
Hanna	(8)	2	0.1
Firefly		1	0.3
Manitou	(8)	0.5	0.2

* Mean of 4 replicates, 2 assessment dates
† Mean of 4 replicates, final assessment date
( ) NIAB rating: 1 = susceptible, 9 = resistant

Table 7. Percent infection of spring barley cultivars in *Rhynchosporium* isolation nurseries in 1994

Cultivar (NIAB rating)		WPBS naturally infected* (see text)	SCRI naturally infected# (see text)
Juno		58	32
Maris Mink		55	25
Alexis	(4)	54	30
Derkado	(3)	54	27
Cooper	(5)	53	28
Prisma	(6)	41	23
Cork	(5)	41	23
Chariot	(3)	41	17
Chad	(5)	35	20
Nomad	(6)	35	17
Heron	(5)	33	24
Riviera	(4)	30	16
Brewster	(7)	27	20
Camargue	(8)	25	4
Optic	(5)	23	34
Felicie	(7)	23	7
Hart	(6)	23	16
Tyne	(6)	22	16
Delibes	(7)	21	16
La Mesita		20	1
Amber		14	4
Dandy	(7)	10	6
Proctor		9	8
Armelle		5	0
Digger		Trace	Trace
Osiris		Trace	0

*Mean of 4 replicates, 2 assessment dates
#Mean of 4 replicates, 3 assessment dates
( ) NIAB rating: 1 = susceptible, 9 = resistant

Table 8. Percent infection of barley cultivars (adult plants) to specific isolates of *Rhynchosporium* under glasshouse conditions with seedling reactions

Isolate Cultivar		RS-93-33G BRV-3		RS-93-1A BRV-1,2,3,4,7		RS-93-52J BRV-3,5,6,7	
Chariot		50*	S†	55	S	50	S
Hart		50	S	50	S	50	S
Derkado		50	S	60	S	50	S
Prisma		50	S	40	S	55	S
Tyne		50	S	25	S	35	S
Heron		50	S	55	S	45	S
Alexis		45	S	60	S	55	S
Dandy		45	S	55	S	55	S
Cooper		40	S	15	S	55	S
Brewster		40	S	20	S	45	S
Chad		40	S	50	S	50	S
Camargue		40	S	40	S	50	S
Delibes		35	S	40	S	30	S
Maris Mink		30	S	40	S	50	S
Nomad		30	S	50	S	50	S
Felicie		30	S	50	S	40	S
Pastoral	(W)	25	S	45	S	50	S
Athene	(W)	25	S	50	S	18	S
Puffin	(W)	20	R	25	S	15	S
Pirate	(W)	20	R	25	S	20	S
La Mesita		15	R	12	R	50	S
Manitou	(W)	5	S	0	R/S	8	S
Digger		0	R/S	0.2	R	0	R
Osiris		0	R	0.3	R	5	S
Armelle		0	R	45	S	0	R
Astrix	(W)	0	R	35	S	0	R
Willow	(W)	0	R	55	S	0	R

* Percentage mean of 2 replicates (adult plants)
† Seedling reaction: S = susceptible; R = resistant;
R/S = low levels of infection
(W) = Winter barley

NET BLOTCH OF BARLEY

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Seedlings tests identified the 1994 isolates as carrying between 1 and 6 specific virulences in various combinations. Additional winter and spring barley cultivars included in the tests displayed a range of responses to the isolates. Glasshouse adult plant tests identified resistance in some spring barley cultivars.

GLASSHOUSE SEEDLING TESTS WITH 1994 ISOLATES

Fifty samples of net blotch were received. This number includes 29 samples received from the CSL/ADAS Disease Survey. The infected leaf samples came from the following winter barley cultivars:

Cultivar	Number of Samples	Cultivar	Number of Samples
Puffin	18	Fighter	2
Pastoral	8	Pipkin	1
Manitou	6	Tempo	1
Intro	4	Linnet	1
Target	3	Sprite	1
Sunrise	2	Finch	1
Fanfare	2		

Several of the samples appeared to display spotting type symptoms. The geographic origins of the samples are given in Table 1.

Table 1. Geographic origins of net blotch samples received in 1994.

Location NIAB region	Number of samples
South East	
Norfolk	12
Kent	5
Suffolk	3
Cambridgeshire	3
Hertfordshire	2
West Sussex	1
South West	
Dyfed	4
Devon	1
Dorset	1
Somerset	1
Central	
South Humberside	1
North East	
Grampian	12
Tayside	1
Northumberland	1

Thirty-five isolates were successfully tested on a set of 13 differential cultivars together with cv. Marinka and an additional 15 spring and 13 winter barley cultivars from the NIAB Recommended List and Recommended List Trials.

Results

The frequencies of individual virulences corresponding to resistance factors in the differential cultivars together with virulence frequencies since 1984 are given in 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 6 virulence factors in others.

Table 2. Virulence frequencies (%) corresponding to each differential cultivar (UK CPV Surveys 1984-1994).

Code Number	Cultivar	1984	1986	1988	1990	1992	1994
1	C.I.5401	0	0	28	0	0	0
2	C.I.6311	22	39	72	13	2	14
3	C.I.9820	0	4	28	0	0	3
4	C.I.739	33	61	50	31	13	14
5	C.I.1243	44	57	39	13	9	23
6	C.I.4795	0	0	33	13	4	6
7	C.I.4502	0	0	33	19	4	11
8	C.I.4979	44	50	56	38	4	29
9	Proctor	55	79	56	56	52	97
10	Code 65(W)	0	0	72	31	9	3
11	C.I.9518(W)	100	96	39	88	56	100
12	Tenn.61-119(W)	44	57	89	75	50	69
13	C.I.9214	0	0	19	19	4	3
No. of isolates tested		9	28	18	15	46	35

W = winter cv.

Table 3. Frequency (%) of virulence of 1994 net blotch isolates to seedlings of winter and spring barley cultivars.

Winter cultivar	Frequency	Spring cultivar	Frequency
Target	100	Alexis	91
Sprite	97	Camargue	91
Manitou	91	Delibes	89
Puffin	88	Heron	83
Epic	86	Prisma	83
Intro	80	Cooper	77
Pastoral	74	Nomad	74
Willow	69	Brewster	66
Linnet	66	Tyne	60
Fighter	60	Felicie	43
Halcyon	46	Derkado	43
Pipkin	43	Dandy	31
Marinka	40	Chariot	29
Gaelic	37	Chad	26
		Hart	26

As in previous years, virulences to cvs Proctor, C.I.9518 and Ten.61-119 were at a high frequency. The spring cvs C.I.5401, C.I.9820, C.I.4795, C.I.4502 and C.I.9214 again expressed resistance to the majority of the isolates. The frequencies of virulence to the additional cultivars included in the seedling tests (Table 3) varied widely between cultivars. Cultivar Target was susceptible to all isolates, whereas cvs Chad and Hart were susceptible to many fewer isolates.

The susceptible cultivars in the seedling tests displayed netting symptoms to all the isolates although several of them had been cultured from leaf samples which showed spots or large circular lesions. All the samples received in 1994 were from winter barleys which, when grown in the field, often show streaking or spotting rather than netting symptoms, particularly at later growth stages. Netting symptoms are more commonly associated with seedlings and spring barley cultivars. The host:pathogen interactions expressed in the seedling tests suggest that the 1994 samples had been infected with *P.t.* var. *teres* which causes netting symptoms rather than *P.t.* var. *maculata* which causes spotting.

ADULT PLANT TESTS

Net blotch of barley became widespread in the UK around 15 years ago. This was due to the expanding winter barley hectarage at that time and the cultivation of highly susceptible cultivars. The emergence of new resistant cultivars and effective fungicides saw the disease become less of a problem in subsequent years. It has been suggested that the widely grown cv. Puffin has contributed to the increased levels of net blotch on winter barley crops in 1993, with the highest levels of the disease seen in the south-west since 1981 (Polley, Slough and Jones, 1993), together with a fairly large number of survey samples in 1994 from geographically diverse origins, indicate a potential increasing threat from the pathogen. To address this threat and to determine whether virulence to currently grown commercial cultivars is becoming more common, there is a need to monitor adult plant:pathogen interactions. Adult plant field tests in previous years have shown it to be very difficult to establish adequate levels of disease on susceptible cultivars in artificially inoculated disease nurseries. Because of this problem, the feasibility of carrying out adult plant tests under controlled conditions in the glasshouse as an alternative to field tests requires examination. Therefore a preliminary evaluation was carried out in 1994.

Fifteen spring and 4 winter barley cultivars were each inoculated with the net blotch isolates:

BNS-94-2	Virulence combination	9, 11, 12
BNS-94-8	Virulence combination	5, 8, 9, 11, 12

Isolate BNS-94-8 was cultured from an infected leaf sample of cv. Fighter showing blotch rather than net or streaking symptoms. Isolate BNS-94-2 was cultured from leaves of cv. Puffin. The plants were placed in dew chambers at 15°C for 24 hours post inoculation and then incubated in a glasshouse at approximately 15°C for 12 days prior

Table 4. Reactions† of barley cultivars (adult plants) to net blotch isolates under glasshouse conditions.

	Isolate	
Cultivar	BNS-94-2 Virulence factors 9,11,12	BNS-94-8 Virulence factors 5,8,9,11,12
Hart	R	R
Heron	R (S)	R (S)
Delibes	S	S
Chad	R	R (S)
Chariot	R	R
Brewster	S	R (S)
Dandy	S	R
Prisma	S	S
Nomad	S	S
Camargue	S	S
Tyne	S	S
Alexis	S	S
Felicie	R	R (S)
Derkado	S	S
Cooper	S	S
Pastoral*	S	S
Manitou*	S	S
Puffin*	S	S
Willow*	S	S

†Mean of 2 replicates
R = resistant, S = susceptible
* = winter cultivar
( ) seedling reaction where different from adult plant reaction

to assessment. The susceptible cultivars had high levels of infection, symptoms being of the netting type to both isolates. They were assessed as being either susceptible or resistant (Clifford and Jones, 1981). Results are given in Table 4. Cultivars Hart, Heron, Chad, Chariot and Felicie expressed resistance to both isolates although cvs Heron, Chad and Felicie were seedling susceptible to either one or both isolates. With the exception of cv. Heron, these spring barleys had been among the most resistant in seedling tests with the 1994 isolates (see Table 3).

Cultivars Brewster and Dandy were resistant to BNS-94-8 but susceptible to BNS-94-2 although the former isolate was identified as carrying additional virulences in seedling tests.

The 4 winter barley cultivars in the tests were susceptible, as they had also been to the majority of the 1994 isolates in seedling tests (Table 3). Cultivars Pastoral and Willow are among a group of varieties assigned a disease rating of 8 to net blotch on the NIAB Recommended List of Winter Barley, 1995. Results from these tests indicate that, when exposed to conditions conducive to the development of net blotch, these cultivars are susceptible. These preliminary tests suggest that host:pathogen interactions are going to be more easily classified under glasshouse conditions than in artificially inoculated field nurseries.

REFERENCES

Polley, R.W., Slough, J.E. and Jones, D.R. (1993). ADAS Survey of Winter Barley Diseases in England and Wales.

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

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

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Of 48 infected samples received in 1994, 56% contained barley yellow mosaic virus (BaYMV) and 60% barley mild mosaic virus (BaMMV). As in previous years, BaMMV was more frequent on malting cultivars (Halcyon, Pipkin, Puffin and Sprite) whereas BaYMV predominated amongst cultivars used for feed. One new "resistance-breaking" outbreak of BaYMV was reported bringing the UK total to 17.

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 through a survey arranged by the Arable Research Centres and also from 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

48 positive samples were received in 1994, slightly fewer than in 1993. The proportions affected by the two viruses were very similar (60% with BaMMV; 56% with BaYMV). For the 33 samples of which the cultivar was known, BaMMV was again predominant on the malting cultivars (Halcyon, Pipkin, Puffin and Sprite) and BaYMV on those grown for feed. Some samples contained both viruses and one new outbreak of "resistance-breaking" BaYMV was detected, bringing the UK total to 17 (Table 1).

Table 1. Mosaic virus samples from 1994, classified by cultivar

Cultivar	BaMMV alone	BaYMV alone	Both	Total Samples
Halcyon	1	0	0	1
Pipkin	2	4	1	7
Puffin	7	0	2	9
Sprite	0	2	0	2
Malting	10	6	3	19
Epic (R)	0	1	0	1
Fighter	0	2	1	3
Manitou	0	1	0	1
Marinka	0	1	0	1
Pastoral	1	5	2	8
Feeding	1	10	3	14
Unknown	10	3	2	15
Total	21	19	8	48

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

In an attempt to examine variation within "resistance-breaking" BaYMV isolates and to compare strains from UK and Japan, a set of 25 Japanese differential cultivars have been planted on several naturally-infested sites (mostly BaYMV-2) for the last three seasons in collaboration with NIAB. The only Japanese cultivars that routinely developed BaYMV symptoms were some of those susceptible to all Japanese strains. Since European *ym4* cultivars appear to be susceptible to only one of the three BaYMV strain groups recognised in Japan (Iida *et al.*, 1992) it appears that there is no simple correspondence between UK isolates and the Japanese strains. The investigations are being continued with a more limited range of cultivars for at least a further year.

REFERENCES

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.

IIDA Y., WATANABE K., TOSHIMA I & OGAWA K. (1992). Reaction of barley (*Hordeum vulgare* L.) cultivars and lines to barley yellow mosaic virus strains. *Japanese Journal of Breeding* **42**, 863-877.

MILDEW OF OATS

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Race 5 (OMV 1,2,3) was identified from all the 32 isolates tested in 1994.

SEEDLING TESTS WITH 1992 ISOLATES

Seventy-four samples of *Erysiphe graminis avenae* were received in 1994 from a wide range of spring (70) and winter (4) oat cultivars. The majority of the samples came from 3 trial sites. Isolates were cultured from 32 of the infected leaf samples and tested on a set of differential cultivars (Table 1).

Table 1. Differential cultivars used for isolate testing

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

Results

Details of the mildew samples tested are given in Table 2. Race 5 was the only race identified. This relatively complex race carries virulence factors OMV-1,2,3 enabling it to attack a wide range of winter and spring oat cultivars. This combination has increased in frequency over a number of years since it was first identified in the field in an oat breeding nursery grown at Aberystwyth in 1969. The increased frequency of race 5 in the pathogen population corresponds with the decline of the simpler races 3 (OMV-1,2), 4 (OMV-1,3) and 2 (OMV-1) which have not been detected for 3, 10 and 11 years respectively. None of the isolates carried virulence to the differential Cc6490 which derives its resistance from *Avena barbata* (OMR-4) although isolates carrying the corresponding virulence (OMV-4) have been identified in recent seasons (Table 3).

None of the winter and spring oat cultivars currently on the NIAB Recommended List appears to carry resistance effective against isolates carrying virulence factors 1, 2 and 3 (race 5). Their pedigrees suggest that some of them have resistances OMR-1 or -2 which are effective to one or other of the less widely virulent races 2 (OMV-1) or 3 (OMV-1,2). Unfortunately, because of the unavailability of these 'simpler' races in the UK at present, it is not possible to identify the resistances carried by these cultivars from the host:pathogen interactions. However, some of the currently grown oat varieties showed good levels of partial or adult plant resistance.

Table 2. Locations and cultivars from which viable mildew samples were received in 1993 with virulences for each sample

Location	Cultivar	Virulence combination (OMV-)
NIAB Region		
<u>Central</u>		
Headley Hall, North Yorkshire	Dula, Keeper, Rhiannon, Melys, Neon	1,2,3
<u>North East</u>		
Cockle Park, Northumberland	Breeding lines (9)*, Balmoral, Neon, Rollo, Rhiannon, Dula, Valiant, Keeper	1,2,3
<u>South East</u>		
Slate Hall, Cambridge	Dula	1,2,3
<u>South West</u>		
Trawsgoed, Dyfed	Rollo, Melys, Samuel, Breeding line	1,2,3
Aberystwyth, Dyfed	Breeding line	1,2,3
Unknown	Keeper, Aberglen, Bruno, Balmoral, Valiant	1,2,3

* Value in parenthesis after cultivar name indicates number of samples of that cultivar

Table 3. Virulence combination (race) frequencies identified from samples received in 1994 compared with previous years' races since 1983

Virulence		Frequency (% total)			No. of isolates in 1994
Group	Race	1992	1993	1994	
OMV 1	2	0	0	0	0
1,2	3	0	0	0	0
1,3	4	0	0	0	0
1,2,3	5	83	80	100	32
1,2,4	6	0	0	0	0
1,2,3,4	7	17	20	0	0
No. of isolates tested		42	35	32	

CROWN RUST OF OATS

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The 26 samples of oat crown rust received in 1994 were from a range of winter (16) and spring (10) oat cultivars. Isolates of *Puccinia coronata avenae* were cultured from 25 of the samples and tested on the International Set of differential cultivars. The majority of the samples came from two sites (Table 1).

Table 1 Locations and cultivars from which crown rust samples were received in 1994 with race identified for each sample.

Location	Cultivar	Race
NIAB Region		
South West		
Dawlish, Devon	Rhiannon, Melys, Bruno, Neon, Valiant, Balmoral, Keeper, Dula, Aberglen, Minerva	251
Trerulefoot, Cornwall	Emperor, Harpoon	205
St Clears, Dyfed	Chamois, Image, Breeding lines (3)*	275
	Mirabel, Kynon, Aintree, Norlys	289
	Breeding lines (3)	251
	Solva	241

*Value in parenthesis after cultivar name indicates number of samples received of that cultivar

Results

The crown rust cultures isolated from the spring oat leaf samples received from Dawlish, Devon were identified as the commonly occurring race 251 which carries virulence to the differential cultivars Appler, Bond and Saia. The cultures obtained from the leaf samples received from the two other locations (Table 1) appeared to comprise a mixture of races. These cultures are tentatively assigned race numbers (Table 1), although tests with single spore isolates cultured from these samples would probably identify different races. All the virulences have been identified in the U.K. previously. The differential cultivars Appler and Saia were susceptible to all the isolates whereas the resistances of Santa Fé, Trispernia, Victoria and Bondvic were effective.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1995

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. 1995.

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

Choosing varieties to grow together

1. Select first-choice variety and locate its Diversification Group (DG). (S) = spring variety.
2. Find this DG under 'Chosen DG' down the left hand side of the table.
3. Read across the table to find the risk of disease spread with 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
Beaufort
Brigadier
Buster
Cadenza
Dynamo
Encore
Flame
Hunter
Hussar
Lynx
Mercia

DG1 contd
Chablis (S)
Promessa (S)
Shiraz (S)
Tonic (S)

DG2
Admiral
Beaver
Haven
Rialto
Slejpner

DG3
Riband

DG7
Consort
Hereward
Spark

DG8
Axona (S)
Baldus (S)

DG0
Genesis
Soissons
Alexandria (S)
Avans (S)
Canon (S)

	Companion DG					
Chosen DG	**1**	**2**	**3**	**7**	**8**	**0**
1	+	+	+	+	+	+
2	+	Y	y	y	Y	Y
3	+	y	Y	y	Y	Y
7	+	y	y	Y	y	Y
8	+	Y	Y	y	Y	Y
0	+	Y	Y	Y	Y	Y

Note: Varieties in DG1 have good resistance to yellow rust spreading from any 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.

April 1995

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF BROWN RUST IN WHEAT 1995

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

Choosing varieties to grow together

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

DG1

Andante
Beaufort
Brigadier
Cadenza
Encore
Flame
Genesis
Hunter
Hussar
Lynx
Axona (S)
Baldus (S)
Canon (S)
Chablis (S)
Promessa (S)
Shiraz (S)

DG2

Slejpner

DG4

Soissons

DG5

Buster

DG7

Hereward
Spark

DG9

Dynamo
Consort

DG10

Avans (S)

DG0

Admiral
Beaver
Haven
Mercia
Rialto
Riband
Alexandria (S)
Tonic (S)
Scamp (S)

Companion DG

Chosen DG	1	2	4	5	7	9	10	0
1	+	+	+	+	+	+	+	+
2	+	B	b	b	b	b	b	B
4	+	b	B	b	b	b	b	B
5	+	b	b	B	b	b	b	B
7	+	b	b	b	B	b	b	B
9	+	b	b	b	b	B	b	B
10	+	b	b	b	b	b	B	B
0	+	B	B	B	B	B	B	B

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

November 1994

VARIETAL DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY 1995

Severe infection may result if mildew spreads between varieties which are susceptible to the same race 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 the 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.

DG 1

Fighter	(W)
Firefly	(W)
Willow	(W)
Alexis	(S)
Atem	(S)
Chariot	(S)
Dandy	(S)
Derkado	(S)
Felicie	(S)
Hart	(S)
Heron	(S)
Riviera	(S)

DG 4

Pipkin	(W)
Tyne	(S)

DG 7

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

DG 8

Manitou	(W)
Camargue	(S)
Nomad	(S)

DG 9

Optic	(S)

DG 10

Epic	(W)
Gaelic	(W)
Sunrise	(W)

DG 0

Fanfare	(W)
Halcyon	(W)
Hanna	(W)
Intro	(W)
Linnet	(W)
Marinka	(W)
Melanie	(W)
Pastoral	(W)
Puffin	(W)
Sprite	(W)
Target	(W)
Blenheim	(S)
Corniche	(S)
Golden Promise	(S)
Prisma	(S)
Triumph	(S)

(W) winter barley, (S) spring barley

November 1994

VARIETAL DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY 1995

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

+ = Low risk of spread of mildew
M = High risk of spread of mildew