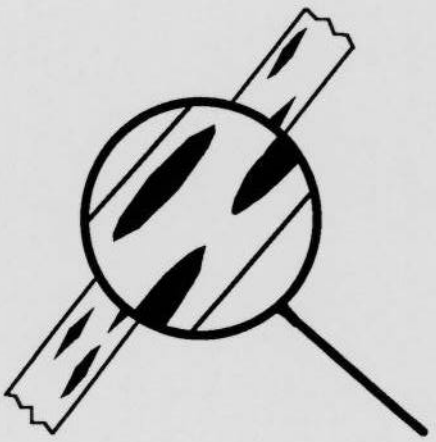
Rosemary Bayles

U.K. CEREAL PATHOGEN VIRULENCE SURVEY



UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

Chairman: Dr R Johnson

Secretary: Dr R A Bayles

National Institute of Agricultural Botany
Huntingdon Road, Cambridge, CB3 OLE
Tel: Cambridge (0223) 276381

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MEMBERS OF THE UK CEREAL PATHOGEN VIRULENCE SURVEY COMMITTEE, 1992-93

Dr R A Bayles	National Institute of Agricultural Botany, Cambridge
Dr J K M Brown	Institute of Plant Science Research, Cambridge Laboratory, Norwich
Dr T L W Carver	Institute for Grassland & Environmental Research, Welsh Plant Breeding Station, Aberystwyth
Mr W Clark	Agricultural Development and Advisory Service, Cambridge
Dr B C Clifford	Institute for Grassland & Environmental Research, Welsh Plant Breeding Station, Aberystwyth
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Mr D Feuerhelm	British Society of Plant Breeders
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Mr E R L Jones	Institute for Grassland & Environmental Research, Welsh Plant Breeding Station, Aberystwyth
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Dr S Wale	Scottish Agricultural College, Aberdeen

CONTENTS

	Page
THE UK CEREAL PATHOGEN VIRULENCE SURVEY	1
EXPLANATION OF TERMS	3
SUMMARY OF RESULTS FOR 1992	4
SURVEY OF WINTER WHEAT DISEASES IN ENGLAND AND WALES 1992 W S Clark	6
SUMMARY OF SURVEY OF WINTER BARLEY DISEASES IN ENGLAND AND WALES 1992 W S Clark	7
MILDEW OF WHEAT A G Mitchell and S E Slater	8
YELLOW RUST OF WHEAT R A Bayles and P L Stigwood	12
BROWN RUST OF WHEAT E R L Jones and B C Clifford	18
BROWN RUST OF WHEAT ADULT PLANT TESTS AT NIAB A G Mitchell	24
MILDEW OF BARLEY A G Mitchell and S E Slater	26
MILDEW OF BARLEY IN NORTHERN IRELAND P C Mercer	32
YELLOW RUST OF BARLEY M H Meadway and W C Hutton	35
BROWN RUST OF BARLEY E R L Jones and B C Clifford	37
RHYNCHOSPORIUM OF BARLEY E R L Jones and B C Clifford	42
NET BLOTCH OF BARLEY E R L Jones and B C Clifford	47
FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY M J Adams	50
MILDEW OF OATS E R L Jones and B C Clifford	52
CROWN RUST OF OATS E R L Jones and B C Clifford	54
VARIETY DIVERSIFICATION SCHEMES FOR 1993	55

THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

OBJECTIVES

The principal objective 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 various ways. Isolates possessing new virulences are used by the National Institute of Agricultural Botany to evaluate the resistance of cereal cultivars in official trials 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 in the National Institute of Agricultural Botany Farmers Leaflet No 8 'Recommended varieties of cereals', the Scottish Agricultural Colleges leaflet "Recommended varieties of cereals', and by the Agricultural Development and Advisory Service.

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 IN THIS REPORT

Specific resistance and specific virulence

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

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

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

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

Terms describing resistance at different growth stages

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

- overall resistances
  are effective at all growth stages

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

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

SUMMARY OF RESULTS FOR 1992

Mildew of wheat

Virulence factors and combinations of virulence factors corresponding to the resistances used in winter wheat cultivars in the UK were recorded at high frequencies. A large proportion of the isolates tested carried a combination of virulence factors enabling them to infect most currently recommended cultivars. However, most of the newer cultivars have moderate or good resistance to mildew which does not depend on these specific resistances.

Yellow rust of wheat

The frequencies of the virulence factors WYV 1, WYV 2, WYV 3, WYV 4, WYV 6 and WYV 9 were all high. Virulence for adult plants of the cultivar Hereward was confirmed.

Brown rust of wheat

Isolates of brown rust from the 1992 leaf samples indicated that the wheat cultivars Zodiac and Hunter carry the resistance factor WBR 1, although Hunter appears to carry additional resistance to a few WBV 1 isolates in seedling tests. Hussar and Brigadier appear to carry a common resistance.

Three new pathotypes of brown rust were tested on adult plants at NIAB. One of the pathotypes, with virulence for the adult plant resistance carried by Slejpner, was virulent on Zodiac, Hussar, Spark and Cadenza, and is probably fairly widespread in the UK. The other two pathotypes, with virulence for the adult plant resistances carried by Pastiche and Virtue respectively, were both virulent on Apollo, Admiral and Cadenza, and one was virulent on Spark. These cultivars have previously shown good resistance to brown rust.

Mildew of barley

Most barley mildew virulence factors and combinations of factors corresponding to resistances used in barley cultivars in the UK were recorded at high frequencies. Consequently, most combinations of specific resistance factors are largely ineffective, although there is some indication that new winter cultivars have moderate resistance which does not depend on any of these specific resistances. Virulence for BMR 9 (mlo) was not detected, and this gene, which is now present in many popular spring barley cultivars, remains effective.

In N.Ireland the virulence BMV 10 and the combined virulences BMV 6a,6b and BMV 6b,6c appeared to be levelling off after the increases of recent years. BMV 7 remained low. There was still no evidence of virulence against BMR 9 (mlo).

Rhynchosporium of barley

Virulence to Osiris (BRR 6) was detected in two isolates. One, identified as race octal 167, carried a previously unidentified virulence combination (BRV 1,2,3,5,6,7). Several winter barley cultivars displayed good levels of resistance to the pathogen in field nurseries. The resistance of the spring barley Digger (BRR?) remains effective.

Brown rust of barley

Seedling tests confirmed the continuing high frequency of virulence for Triumph in the brown rust population. Field isolation nurseries showed that a number of winter barley cultivars were resistant to the two isolates used.

Net blotch of barley

Isolates carrying between one and ten virulence factors were identified from the 1992 net blotch samples. Twelve isolates failed to produce a susceptible reaction on any of the seedling differential cultivars although they were virulent on several of the additional winter and spring barley cultivars included in the tests.

Fungally-transmitted mosaic viruses of barley

Of 167 infected samples received in 1992, 53% contained barley yellow mosaic virus (BaYMV) and 60% barley mild mosaic virus (BaYMV). These proportions were similar to 1991 and, as in previous years, BaMMV was more frequent on malting cultivars (Halcyon, Pipkin and Puffin) whereas BaYMV predominated amongst cultivars used for feed. Three new "resistance-breaking" outbreaks of BaYMV were reported bringing the UK total to 15.

Mildew of oats

Virulence to the resistance derived from Avena barbata, (OMV 4) which increased rapidly in the oat mildew population from 1989 to 1991, showed a sharp decline in frequency in 1992. It occurred solely in combination with OMV 1, 2 and 3 (Race 7). Race 5 (OMV 1,2,3) was the only other race identified from the 1992 samples.

SURVEY OF WINTER WHEAT DISEASES IN ENGLAND AND WALES 1992

W.S. Clark
ADAS Cropping and Horticulture Development Centre, Cambridge.

Summary

From a stratified sample, 397 randomly selected crops of winter wheat were examined for foliar and stem base diseases during the milky-ripe growth stage, which occurred between mid-June and mid-July. 50% of the samples were received by 3 July, 16 days earlier than in 1991. All foliar diseases were less severe nationally than in 1991, and in total were less important than in any previous year in which a winter wheat survey has been undertaken. Septoria tritici was the most severe foliar disease for the third year running, affecting 1.2% of the second leaf. The highest levels were recorded in Wales and the south-east (Wye). Mildew affected 0.5% of leaf 2, but it was only more important than in 1991 in some southern areas. Septoria nodorum and brown rust both affected less than 0.1% of leaf 2 and levels of yellow rust nationally were insignificant. 10.9% of stem bases were affected by moderate or severe symptoms, a higher level than recorded in 1989 and 1990, but down slightly compared to 1991. Sharp eyespot levels were low, with 3.8% of stems having moderate or severe symptoms. Stem base fusarium was the only disease to show an increase in both incidence and severity compared to 1991 with moderate or severe nodal and internodal symptoms occurring on 12.5% and 4.8% of stems respectively. Once again, however, very few stems were affected by severe symptoms. The incidence of fusarium ear blight also increased, with the disease being recorded in 17.6% of fields and 1.8% of ears affected in total. Ear blight symptoms were most frequent in the south-west. Visible take-all patches were recorded in 11.0% of crops. Plants with BYDV symptoms were seen in 10.2% of crops but patches of affected plants were seen in only 2.4% of fields.

Riband was the most popular variety recorded for the second consecutive year, accounting for 32.7% of crops in the stratified survey sample. The proportion of crops of Haven and Beaver increased to 11.6% and 10.1% respectively, but the popularity of Mercia, Hornet and Apollo declined. The highest level of Septoria tritici was recorded in Riband and the lowest level in Apollo, while mildew was more severe on Apollo than on other varieties, reflecting the NIAB varietal disease resistance ratings. Some diseases, particularly eyespot and take-all were affected by agronomic factors such as previous cropping and sowing data. Fungicide sprays were used on 94.7% of the crops sampled, the most popular regime (34.5% of crops) being a first spray at growth stage 31 followed by a second spray at or after growth stage 59. The pattern of fungicide usage indicated that a significant proportion of sprays were applied earlier than in 1991, but total fungicide usage was unchanged with crops receiving, on average, 2.0 sprays each. 21.9% of crops were grown from seed treated with a non-mercurial fungicidal seed dressing.

Information on seed treatments was available for 365 of the crops included in the stratified sample. 80 crops (21.9%) were grown from seed treated with a non-mercurial fungicidal seed dressing (Baytan), slightly higher than the figure of 17.5% recorded in the previous year's survey. 72.1% of crops were grown from seed treated with a single- or dual- purpose dressing, a decrease of 7.6% compared to the previous year. Untreated seed was used for 2.7% of crops compared to 2% in 1991.

SURVEY OF WINTER BARLEY DISEASES IN ENGLAND AND WALES 1992

W.S. Clark
ADAS Cropping and Horticulture Development Centre, Cambridge

Summary

From a stratified sample, 377 randomly selected crops of winter barley were examined for foliar and stem base diseases during the watery-ripe to early-milk stage in June 1992. 50% of the samples were received by 17 June, 9 days earlier than in 1991. Total foliar disease levels were lower than in any previous winter barley survey. Mildew was the most widespread and severe foliar disease, affecting 2.9% of the second leaf. In the south-east (Wye) it was more severe than for several years, but in most other areas it was less important than in 1991. Brown rust nationally affected 1.7% of leaf 2 and was most prevalent in the south-east, the south-west and Wales. Both rhynchosporium and net blotch affected 0.6% of leaf 2, and were more common in Wales and the south-west than elsewhere. In contrast to the foliar diseases, stem base diseases, with the exception of internodal fusarium, showed an increase in severity compared to the previous year. 14.3% of stem bases had moderate or severe symptoms of eyespot, the second highest level recorded in these surveys. Moderate or severe sharp eyespot was recorded on 3.0% of stems and moderate or severe symptoms of nodal fusarium on 15.3%, almost twice the level found in the previous year.

Marinka was the most popular cultivar encountered for the third consecutive year, accounting for 29% of the crops in the stratified survey sample. Pastoral and Puffin increased their share of the survey samples, but there was a decline in the popularity of Magie and Frolic compared to 1991. Mildew was most severe on Pipkin and least severe on Halcyon, reflecting their NIAB resistance ratings. Puffin carried a very low level of brown rust and the highest level of rhynchosporium was again recorded on Igri. Agronomic factors such as sowing date and previous crops were associated with different disease levels. Fungicide sprays were used on 93% of crops, the most popular regime being a single spray at growth stage 31 (35% of crops). The use of prochloraz at growth stage 31 was associated with reduced levels of eyespot. 27% of crops received a fungicidal spray at growth stage 31 followed by a second spray after flaf leaf emergence. 51% of crops received a single fungicide spray application, 35% were sprayed twice and 6.5% received three or more sprays. 22% of crops were grown from untreated seed.

MILDEW OF WHEAT

A. G. Mitchell and S. E. Slater

National Institute of Agricultural Botany, Cambridge

Virulence factors and combinations of virulence factors corresponding to the resistances used in winter wheat cultivars in the U.K. were recorded at high frequencies. A large proportion of the isolates tested carried a combination of virulence factors enabling them to infect most currently recommended cultivars.

INTRODUCTION

Recent surveys of wheat mildew have recorded a high frequency of virulence factors corresponding to the resistance genes used in wheat cultivars in the U.K. (Slater *et al.* 1989, Brown *et al.* 1990, Mitchell & Slater 1991, 1992). Consequently, these resistance genes do not provide effective resistance to mildew. The survey in 1992 continued to monitor the frequencies of virulences and combinations of virulences matching the main resistance genes, but was carried out at a reduced level compared to previous years.

METHODS

Single colony isolates were derived from samples of infected leaves, predominantly from newer cultivars with good resistance to mildew. No samples of airborne spores were taken in 1992. The infected leaves were taken mostly from variety trials plots at the following sites:

Bridgets, Hampshire	11 isolates	Thriplow, Cambridgeshire	26 isolates
Wye, Kent	25	Spalding, Lincolnshire	30
Abington, Cambridgeshire	10	Headley Hall, Yorkshire	42
Burwell, Cambridgeshire	2	Alnwick, Northumberland	4
NIAB, Cambridge	43	Shoreswood, Northumberland	1
Total	194 isolates		

The source cultivars were:

Winter cultivars			
Hereward, Genesis, Apostle (WMR0)	18 isolates	Beaver, Haven, Hunter (WMR7)	34 isolates
Talon (WMR2)	6	Admiral (WMR2,7)	10
Estica (WMR2,6)	8	Zodiac (WMR6,7)	13
Hussar (WMR4,6)	12	Riband (WMR2,4,8)	4
Brigadier (WMR2,?6)	14	Mercia (WMR8,Tal)	2
Torfrida (WMR2,4,6)	10	Spark (WMRp,?2,?4)	12
Apollo (WMR2,4,7)	2	Soissons (WMR?)	4
Spring cultivars			
Alexandria (WMR0)	2	Cadenza (WMR,?Ax)	15
Troy (WMR4,r?)	2	Tonic (WMRp)	6
Axona (WMR9,Ax)	4	Baldus, Canon, Concerto, Promessa, Rascal (WMR?)	16
Total	194 isolates		

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

Table 1. *Differential cultivars used to determine virulence factors in isolates of wheat mildew in 1992.*

WMR group	Resistance genes	Cultivar
0	None	Cerco
2	*Pm2*	Galahad
4b	*Pm4b*	Armada
5*	*Pm5*	Hope
2,6	*Pm2, Pm6*	Brimstone
7	*Pm8*	Clement
8*	*Mli*	Flanders
8,m	*Mli*, unknown	Mercia
9	*Mld*	Maris Dove
p	Unknown	Tonic
q	Unknown	Broom
5,8,r	*Pm5, Mli*, unknowm	Sicco
'Sona'	Unknown	Wembley
'Axona'	Unknown	Axona
2, 'Talent'	*Pm2*, Unknown	Brock

* WMR5 (*Pm5*) and WMR8 (*Mli*) are probably identical (Heun & Fischbeck 1987) Not all isolates were tested on Hope (WMR5, *Pm5*)

RESULTS

Virulence Frequencies

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

Virulence factor	Frequency of virulence factors (%)		
	1992	1991	1990
2	99	100	99
4b	73	69	52
6	76	80	69
7	86	80	66
8	90	92	-
9	27	-	-
m	60	50	34
p	24	9	-
q	31	-	-
8,r	32	38	-
'Sona'	23	-	-
'Axona'	17	10	-
2, 'Talent'	60	54	-
No. of isolates tested	194	300	290

The frequencies of WMV2, 4b, 6, 7, 8, 9, m, p, q, 8 with r, 'Sona', 'Axona', and 2 with 'Talent' are shown in Table 2. Not all isolates were tested on Hope (WMR5, *Pm5*), and therefore the frequency of WMV5 is not given. The results for isolates tested on Hope (WMR5, *Pm5*) and Flanders (WMR8, *Mli*) were consistent with these specific resistances being identical. All isolates carrying WMVm also carried WMV'Talent' and it is possible that the corresponding resistances are identical.

All virulence factors were recorded at high frequencies in 1992, as in previous years. The frequencies of virulence factors 4b, 7, m, p and 'Axona' showed an increase compared to 1991 or 1990. The steady increase in WMV4b from 1990 to 1992 is probably due to the popularity of Riband (WMR2,4,8). The increase in WMV7 corresponds to increasing popularity of Beaver and Haven (WMR7), although other cultivars with WMR7, such as Apollo, Slejpner and Hornet, have been widely grown since 1987. The only commercially grown cultivar with WMRm is Mercia, which has occupied about 20% of the national wheat acreage since 1988. This may explain the gradual increase in the frequency of WMVm. The increases in WMVp and WMV'Axona' probably reflect the presence in trials of the winter cultivars Cadenza and Spark, which have spring cultivars as parents. The parents of Cadenza are Axona and Tonic, and the parents of Spark are Moulin and Tonic.

Several reports were received of higher than expected levels of mildew on the winter wheat cultivars Beaver, Haven and Hunter. The results of virulence tests of isolates from these cultivars did not suggest that there has been any change in virulence, and there was no indication of increased infection of Beaver, Haven and Hunter in NIAB variety trials in 1992.

Complexity of Isolates

The frequencies of the most common pathotypes defined by WMV2, 4, 6, 7 and 8 are given in Table 3. Almost 80% of isolates carried at least four or more of these virulence factors, and also carried one or more of the uncharacterised resistance factors. The most frequent pathotype, WMV2,4,6,7,8, would be able to infect almost all of the widely grown wheat cultivars.

Table 3. *Frequencies of the most common wheat mildew pathotypes, defined by WMV2, 4, 6, 7 and 8, collected from infected leaves in 1992, 1991 and 1990.*

Pathotype	Frequency of pathotypes (%) 1992	1991	1990
2,4,6,7	8	4	28
2,4,6,8	4	5	3
2,4,6,7,8	50	55	6
2,4,7,8	7	6	1
2,6,7,8	10	10	6
2,6,8	3	5	9
2,7,8	9	6	5
Total no. of pathotypes	14	17	20
No. of isolates	194	317	290

Resistance Factors in New Cultivars
The specific resistance factors in winter cultivars on the United Kingdom Recommended List of Cereal Varieties 1993 are given in Table 4.

Table 4. *Specific mildew resistance factors of winter wheat cultivars on the United Kingdom Recommended List of Cereal Varieties 1993.*

WMR0	**WMR 2,7**	**WMR2,4,8**
Genesis	Admiral	Riband
Hereward		
	WMR2,4,6	**WMR4**
WMR2	Hussar (2?)	Brigadier (+2 and/or 6)
Norman	Torfrida	
		WMR8
WMR7	**WMR2,4,7**	Mercia (+m)
Beaver	Apollo	
Haven		**WMRp**
Hunter		Spark (+?2,?4)

CONCLUSIONS

The results of the 1992 survey of wheat mildew were consistent with those of 1991 and 1990. The virulence factors and combinations of virulence factors corresponding to the specific resistances of the most popular wheat cultivars in the U.K. were recorded at high frequencies. However, most of the newer cultivars of wheat have moderate resistance to mildew which does not depend on specific resistance genes.

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YELLOW RUST OF WHEAT

R A Bayles and P L Stigwood

National Institute of Agricultural Botany

The frequencies of WYV 1, WYV 2, WYV 3, WYV 4, WYV 6 and WYV 9 were all above 70%. Virulence for adult plants of the cultivar Hereward was detected.

INTRODUCTION

The principal aim of the wheat yellow rust survey is to detect increased virulence for specific resistances to Puccinia striiformis (WYR factors). In addition, specific resistances in current and new cultivars are identified. Specific resistances identified to date, the resistance genes where known, differential cultivars possessing each resistance and the year of first detection of virulence (WYV) in the UK population of P.striiformis are given in Table 1. Additional cultivars with relevant resistance were included in seedling tests (Table 2).

Table 1. Resistance factors to Puccinia striiformis and differential cultivars

WYR	Gene	Type*	Differential Cultivar(s)**	WYV detected
WYR 1	Yr 1	O	Chinese 166,	1957
WYR 2	Yr 2	O	Heine VII	1955
WYR 3	Yr 3a + 4a	O	Vilmorin 23, Cappelle Desprez	1932
WYR 4	Yr 3b + 4b	O	Hybrid 46	1965
WYR 5	Yr 5	O	T. spelta album	-
WYR 6	Yr 6	O	Heines kolben	1958
WYR 7	Yr 7	O	Lee, Tommy	1971
WYR 8	Yr 8	O	Compair	1976
WYR 9	Yr 9	O	Riebesel 47/51	1974
			Kavkaz 4 X Federation	
WYR 10	Yr 10	O	Moro	-
WYR 11	-	A	Joss Cambier	1971
WYR 12	-	A	Mega	1969
WYR 13	-	A	Maris Huntsman	1974
WYR 14	-	A	Hobbit	1972

* O = Overall A = Adult Plant

** Differential cultivars used in 1992 seedling tests are underlined

Table 2. Additional cultivars included in seedling differential tests

Cultivar	WYR
Tara	WYR 7,9
Talon	WYR Rx (Carstens V + ?)
Hereward	WYR Rx (Carstens V + ?)
Parade	WYR R
Brigadier	WYR R
Hussar	WYR R
Cadenza	WYR R
Tonic	WYR R

Rx = specific resistance not fully identified
R = resistant to all isolates prior to 1992 survey

METHODS

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

1992 isolates

The incidence of yellow rust in the UK in 1992 was low. The UKCPVS tested 77 isolates, from 37 different cultivars, in seedling tests, using the differential cultivars listed in Tables 1 and 2. Nearly all isolates came from eastern areas of England and Scotland.

1991 isolates

16 isolates were tested on adult plants of 30 cultivars in Polythene tunnels and on seedlings of a subset of 15 cultivars with unidentified resistances. the isolates included twelve from the 1991 survey, two from the previous year's inoculated adult plant tests and two control isolates from 1990. At the seedling stage, eleven of the 1991 isolates were virulent on Talon, ten on Hereward and two on Hussar. Virulence for Talon (seedling and adult plant) was first detected in 1990. However, 1991 was the first year in which isolates with seedling virulence for Hereward and for Hussar were detected. The first opportunity to test these isolates on adult plants was therefore during the 1992 season.

Table 3. Isolates of Puccinia striiformis used in adult plant tests

Isolate Code	Source: Cultivar	Source: Location	WYV Factors	Additional Virulence*
91/10	Talon	Norfolk	1,2,3	Ta He
91/17	Spark	Scotland	1,2,3,4,6,7,9	Ta He Hu
91/18	NL cv	Scotland	1,2,3,4,6,9	Ta He Hu
91/22	Slejpner	Humberside	1,2,3,4,6,9	- He -
91/23	Hereward	Cambs	1,2,3,4,6,9	Ta He -
91/27	Axial	Norfolk	1,2,3,4,9	Ta He -
91/30	NL cv	Cambs	2,3,4,7,9	- - -
91/31	Talon	Cambs	1,2,3	Ta He -
91/33	Talon	Cambs	2,3,4,7,9	Ta - -
91/40	Talon	Lincs	1,2,3,9	Ta - -
91/505	Tara	inoc 90/43	1,2,3,6,7,9	- - -
91/511	Axial	inoc 90/61	1,2,3,4,9	Ta He -
91/601	Hereward	Cambs	2,3,4,6	Ta He -
91/703	Hereward	Cambs	1,2,3,4,9	Ta He -
90/80	Talon	Lincs	1,2,3	Ta - -
90/85	Haven	Scotland	1,2,3,4,6,9,13,14	- - -

* virulence for additional cultivars at seedling stage:-
Ta = Talon, He = Hereward, Hu = Hussar

RESULTS

1992 virulence frequencies from seedling tests

Seedling virulence frequencies are given in Table 4.

The frequencies of WYV 1, WYV 2, WYV 3, WYV 4, WYV 6 and WYV 9 remained high. There was a slight reduction in the frequency of WYV 9, probably associated with declining numbers of cultivars with resistance based on WYR 9 and an increase in WYV 6. Virulence for Talon and for Hereward remained at around the 1991 level. Virulence for Brigadier and Hussar, two cultivars with the adult plant resistant cultivar Rendezvous in their parentage, was detected at a moderate frequency, although no samples had been received from the cultivars themselves.

Adult plant tests

The results of adult plant tests are given in Table 5.

Isolates which were virulent on seedlings of Talon generally gave increased levels of infection on adult plants of the cultivar. This indicates that Talon has a specific resistance which is effective at all growth stages, without additional adult plant resistance. Although virulence for Talon was first detected in a relatively simple pathotype, WYV 1,2,3 (isolate 90/80), it is now appearing in more complex backgrounds.

Table 4. Virulence factor frequency (%)

WYV Factor	1978	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92
WYV 1	73	83	95	71	63	85	75	76	78	87	68	62	85	91	88
WYV 2	97	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 3	100	100	85	95	100	100	100	100	100	100	100	100	100	100	100
WYV 4	27	17	15	29	37	20	31	45	70	47	78	97	91	86	86
WYV 5	0	0	0	0	0	0	0	*	*	*	*	*	*	*	*
WYV 6	26	17	25	31	29	26	64	90	96	89	72	57	69	64	88
WYV 7	0	0	0	5	5	0	3	3	22	8	6	2	9	19	7
WYV 8	0	0	0	0	2	0	0	*	*	*	*	*	*	0	0
WYV 9	0	0	0	5	2	23	31	3	4	5	66	99	94	88	76
WYV 10	0	0	0	0	0	0	0	*	*	*	*	*	*	*	*
No. of isolates	66	30	20	42	41	63	36	29	23	52	71	156	67	42	77
Virulence for additional test cvs															
Tara WYR ?7,9													18	21	20
Talon WYR Rx (Carstens V + ?)														41	38
Hereward WYR Rx (Carstens V + ?)														36	47
Parade														-	3
Brigadier														-	40
Hussar														12	29
Cadenza															0
Tonic															1

* differential not included in test

There was a poor correlation between seedling and adult plant virulence for Hereward. Many of the isolates which were virulent on seedlings of the cultivar did not infect adult plants. Only one isolate, 91/601 gave a high level of infection on adult plants, and another, 91/703, an intermediate level. This suggests that Hereward has a specific adult plant resistance in addition to an overall resistance. It has previously been suggested that the overall resistance of Hereward, Talon, Axial and Estica is derived from Carstens V (UKCPVS Annual Report for 1991).

Isolates with virulence for seedlings of Hussar failed to infect adult plants of the cultivar, showing that it has effective adult plant resistance, which may or may not prove to be specific.

Six new cultivars were included in tests. Four of these, Brigadier, Cadenza, Hunter and Zodiac had very high levels of adult plant resistance to all isolates. Brigadier, unlike its parent Rendezvous, was completely resistant at the seedling stage. Cadenza appears to have the same specific resistance as the spring wheat cultivar Tonic, which is in its parentage. Hunter may possess the resistance WYR 6,9 combined with adult plant resistance. Zodiac is susceptible to some isolates at the seedling stage, but its resistance remains unidentified.

The fifth new cultivar Spark had a generally high level of adult plant resistance. There was some indication however that the 'Hereward - virulent' isolate gave increased infection on Spark. The remaining new cultivar, Genesis, appears to have no specific resistance.

REFERENCE

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

Table 5 Adult Plant Tests 1992. Mean per cent leaf area infection (mean of 5 assessments)

Cultivar	Isolate	91/ 601	91/ 703	91/ 33	91/ 27	91/ 18	91/ 10	90/ 80	91/ 31	91/ 40	91/ 17	91/ 511	91/ 22	91/ 505	91/ 30	91/ 23	90/ 85
	WYV factors																
	WYR factors	2,3,4,6,14	1,2,3,4,9,13 14	2,3,4,7,9,14	1,2,3,4,9,13, 14	1,2,3,4,6,9, 13,14	1,2,3	1,2,3	1,2,3	1,2,3,9	1,2,3,4,6,7, 9,13,14	1,2,3,4,9,14	1,2,3,4,6,9, 13,14	1,2,3,4,6,9, 13	2,3,4,7,9,14	1,2,3,4,6,9, 13,14	1,2,3,4,6,9, 13,14
Parade	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rendezvous	0+APR	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Torfrida	Rx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hussar	Rx	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brigadier	R	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
Cadenza	R Tonic	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Hunter	?6,9 +	0	1	0	0	1	0	0	0	0	2	0	1	0	0	1	1
Zodiac	Rx	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
Mercia	3+APR	4	1	0	1	1	1	1	2	2	0	0	0	0	0	0	0
Arminda	0+APR	2	4	2	1	3	1	2	3	0	0	1	0	0	0	0	0
Hereward	Carstens V +	10	5	3	1	1	1	0	0	1	1	2	0	0	0	0	0
Talon	Carstens V +	23	15	13	11	17	12	17	14	8	7	5	3	3	2	1	2
Axial	Carstens V +	21	18	18	18	14	18	16	17	9	7	21	3	2	2	2	3
Estica	Carstens V +	2	1	1	0	2	0	1	2	1	0	0	0	0	0	0	0
Spark	Rx	4	0	0	0	0	0	0	0	0	2	1	1	0	0	1	1
Kinsman	6,13	8	6	2	7	10	4	2	0	1	10	3	10	5	1	14	9
M.Huntsman	2,13	1	2	3	6	2	2	1	3	3	7	3	3	0	1	5	4
Hustler	1,2,13	1	9	2	13	11	3	2	1	5	11	7	11	1	5	20	9
Riband	13	0	8	5	8	7	4	3	5	3	11	9	10	0	3	11	8
Hobbit	14	16	12	10	10	8	6	0	2	3	13	8	15	0	14	15	12
Clement	9	4	49	17	24	16	12	8	6	17	20	23	31	10	19	23	16
Apollo	9	0	16	11	17	6	1	0	0	2	7	12	7	2	1	7	7
Admiral	9	0	12	0	4	7	3	0	0	2	7	5	10	1	1	10	5
Hornet	6,9	1	21	3	12	15	14	9	3	0	19	5	19	12	6	20	15
Haven	6,9	1	10	1	6	10	11	4	1	0	10	5	9	7	1	12	9
Beaver	6,9	1	8	2	7	7	5	0	1	0	10	2	9	0	0	12	7
Brock	7,14	0	0	11	0	0	1	1	0	0	6	0	1	0	12	0	4
Tommy	7	0	0	16	0	0	7	10	1	0	13	0	0	5	15	1	6
Tara	7,9	0	0	0	0	0	1	0	0	0	4	0	0	0	0	0	0
Genesis	0	3	6	3	3	7	3	5	5	3	5	1	4	0	1	3	2

BROWN RUST OF WHEAT

E.R.L. Jones and B.C. Clifford

AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station, Plas Gogerddan, Aberystwyth, Dyfed SY23 3EB, U.K.

Isolates of brown rust cultured from the 1992 leaf samples identified the wheat cvs Zodiac and Hunter as carrying the resistance factor WBR-1, although cv. Hunter appears to carry additional resistance to a few WBV-1 isolates in seedling tests. Cultivars Hussar and Brigadier appear to carry a common resistance. Adult plant tests in field isolation nurseries and in controlled environmental conditions in the glasshouse enabled some of the wheat cultivars to be grouped on the basis of their responses to the isolates.

GLASSHOUSE SEEDLING TESTS WITH 1992 ISOLATES

Twenty one samples of *Puccinia recondita* were received from winter (20) and spring (1) wheat cultivars in 1992. This number included 16 sent from the ADAS Cereal Disease Survey. The geographic origins of the samples are given in Table 1.

Table 1. Geographical origin of 1992 wheat brown rust isolates

Location	Number of samples
England (ADAS region)	
East	13
South-west	3
West-central	3
Wales	2

Isolates were obtained from 17 of the samples and tested on differential cultivars which comprised the standard WBR reference cultivars, cv. Thatcher backcross lines carrying different Lr resistance factors and 8 other spring and winter wheat cultivars from the NIAB Recommended List and Recommended List Trials (Table 2).

Table 2. Differential cultivars

Standard differential cultivars		Thatcher Lr lines	Spring* and winter cultivars
Clement	(WBR-1)	Lr 1	Rascal*
Maris Fundin	(WBR-2)	Lr 2a	Promessa*
Norman	(WBR-2)	Lr 3	Concerto*
Hobbit	(WBR-2)	Lr 3bg	Zodiac
Sappo	(WBR-3)	Lr 3ka	Hunter
Maris Halberd	(WBR-4)	Lr 9	Cadenza
Gamin	(WBR-6)	Lr 15	Hussar
Sterna	(WBR-7)	Lr 19	Brigadier
Sabre	(WBR-7)	Lr 24	
Armada	(WBR-0)		

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

Results

Isolate/cultivar interactions were classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4). In cultivars with temperature-sensitive resistance factors (WBR-2,3,4 and 7), interactions were classified as susceptible only if that reaction was expressed at both temperatures. The virulence combinations identified and their frequencies compared with the previous five years are given in Table 3. The frequencies of individual virulences over the same period are given in Table 4.

Table 3. Virulence combinations and their frequencies identified from the 1992 isolates compared with the previous five years

WBR virulence formula	Frequency					
	1987	1988	1989	1990	1991	1992
6	0.20	0.04	0	0.02	0	0.06
1,6	0.03	0	0	0	0	0
2,6	0.61	0.96*	0.33	0.27	0.06	0.12
1,2,6	0.08	0	0.67	0.67	0.82	0.76
2,6,7	0	0	0	0.04	0	0
1,2,4,6	0	0	0	0	0.06	0
1,2,3,4,6	0.08	0	0	0	0.06	0.06
Number of isolates tested	36	26	12	51	18	17

*3 isolates did not carry virulence to all three WBR-2 differential cultivars

The majority of isolates tested in recent years have been identified as carrying virulence factors 2 and 6. More recently virulence to cv. Clement (WBR-1) has combined with these. Virulence to WBR-1, derived from a rye translocation, has been increasing in frequency, reflecting the deployment of this resistance in a number of wheat cultivars currently on the NIAB Recommended List. Only one isolate, WBRS-92-2, failed to overcome the temperature-sensitive resistance present in cvs Maris Fundin, Hobbit and Norman (WBR-2), confirming the high frequency of this virulence. This isolate gave a reaction of a mixed resistant nature on all three cultivars. The resistance of cv. Sappo (WBR-3), which is more effective at the lower temperature, was overcome by one of the isolates. This isolate also carried virulence to cv. Halberd (WBR-4), virulence to which remains at a low frequency (0.06) in the pathogen population. All the 1992 isolates were avirulent on cvs Sterna (WBR-7) and Sabre (WBR-7) at 25°C, but gave more susceptible reactions of a mostly mixed type at 10°C. The winter wheat cvs Zodiac and Hunter reacted similarly to cv. Clement (WBR-1) to the 1992 isolates, although one isolate, WBRS-92-19, which was compatible with cvs Clement and Zodiac failed to infect cv. Hunter. Two isolates identified as carrying WBV-1 from the 1991 survey also failed to infect cv. Hunter which had shown a similar pattern of response as cv. Clement to the other 1991 isolates. These results suggest that cvs Zodiac and Hunter carry resistance factor WBR-1, but that cv. Hunter carries additional resistance which is effective against some WBV-1 isolates. The spring wheat cvs Concerto and Rascal carry a temperature sensitive resistance more effective at the low temperature regime. Both cultivars were susceptible to the 3 same isolates, one of which was the only isolate cultured from the 1992 samples virulent on the differential cvs Sappo (WBR-3) and Halberd (WBR-4).

Table 4. Virulence frequencies corresponding to each differential cultivar (UK CPV Surveys 1987-1992)

Cultivar	WBR factor	Frequency					
		1987	1988	1989	1990	1991	1992
Clement	1	0.11	0	0.67	0.66	0.94	0.82
Fundin	2*	0.78	0.96	1.00	0.98	1.00	0.94
Norman	2*	0.78	0.85	1.00	0.98	1.00	0.94
Hobbit	2*	0.78	0.88	1.00	0.98	1.00	0.94
Sappo	3*	0.08	0	0	0	0.06	0.06
Halberd	4*	0.08	0	0	0	0.11	0.06
Gamin	6	1.00	1.00	1.00	1.00	1.00	1.00
Sterna	7*	0	0	0	0.04	0	0
Sabre	7*	0	0	0	0	0	0
Armada	0	1.00	1.00	1.00	1.00	1.00	1.00
Number of isolates		36	26	12	51	18	17

*Temperature sensitive

Seedling test results with the 1992 isolates indicate that the winter wheat cvs Brigadier and Hussar carry a common resistance, being susceptible to only one isolate, namely WBRS-92-13. The resistance is temperature-sensitive which is more effective at the high temperature regime.

Cultivar Promessa was resistant to all the isolates at 10°C and 25°C. Cultivar Cadenza was susceptible to all the isolates at 25°C but was resistant to 9 of these at the lower temperature. The reactions of the Thatcher-Lr backcross lines, which carry known specific Lr genes, to the 1992 isolates are given in Table 5. The resistances conferred by Lr1, Lr2a, Lr3bg, Lr3Ka and Lr9 are more affective at the high temperature regime. The converse is true of Lr15. The lines Lr19 and Lr24 expressed resistance at both temperatures to all the isolates with which they were inoculated. Virulence to Lr19 has not yet been detected in the UK population.

Table 5. Reaction of Thatcher-Lr backcross lines to 1992 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	2*	6	7	7	14	3	10	11	11
R/MR	MS/S							2		
MS/S	R/MR	12	10	9	5	2	9			
MS/S	MS/S			1						

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

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Thirty-two winter and 10 spring wheat cultivars were sown in each of two nurseries in the 1991-92 season. The nurseries were inoculated with one or other of the following isolates of *P.recondita*, obtained from the 1991 survey.

Isolate	Origin
WBRS-91-66 (WBV-1,2,6)	Virtue, PBI, Cambridge
WBRS-91-61 (WBV-6)	Lasko (Triticale)

The virulence factors carried by the two isolates were identified from seedling tests and it may be that the isolates carry additional virulence(s) which can only be identified at the adult plant stage of growth.

Results

These are summarised in Table 6. High levels of disease built up on the susceptible spreader cultivars within the winter and spring nurseries. Using data from the field nurseries, together with results from seedling and limited data from adult plant tests carried out under controlled environmental conditions, some of the wheat cultivars were placed into resistance groups.

Group 1 (WBR-1) Cultivars: Cultivars within the first group have been identified as responding in a way similar to cv. Clement (WBR-1) in seedling tests to the isolates in the year(s) in which each was tested. Only cv. Hunter, included in 1991 and 1992 seedling tests, differed from cv. Clement in that it expressed resistance to three isolates identified as carrying WBV-1. Also, one isolate, WBRS-91-65, was compatible with cvs Clement, Slejpner, Admiral, Zodiac and Apollo but lacked virulence to cvs Haven and Beaver.

Adult plant tests in field isolation nurseries, inoculated with defined isolates of the pathogen, have in recent years indicated that some cultivars identified in seedling tests as carrying WBR-1 express resistance at the adult plant stage of growth to isolates carrying the corresponding virulence factor WBV-1.

Within group 1, cvs Clement and Apollo react similarly to all the isolates in all of the tests.

Cultivars Haven and Beaver responded similarly to cv. Clement in all tests except to isolate WBRS-91-65 in seedling tests and to the same isolate in adult plant tests carried out under controlled environmental conditions when they expressed resistance at both post-inoculation incubation temperatures (10°C and 25°C). These two cultivars were also resistant to isolate WBRS-87-28 (WBV-1,2,5,6) in 1989 field tests, suggesting they carried WBR-1 plus adult plant resistance in common with cv. Slejpner. It may be that cvs Haven and Beaver carry additional resistance effective at both the seedling and adult plant stages of growth to some isolates of *P. recondita* identified as carrying virulence factor WBV-1. Cultivars Admiral and Hornet are also placed in this sub-group although data are limited.

Cultivar Slejpner (WBR-1 + adult plant resistance) was resistant in both 1992 field nurseries as were cvs Zodiac and Hunter. These two cultivars were susceptible to isolate WBRS-91-66 (WBV-1,2,6) in seedling tests. Cultivar Slejpner was not tested as a seedling with this isolate but has previously expressed high levels of resistance as an adult plant to WBV-1 isolates to which it was susceptible as a seedling. Virulence to the resistance carried by cv. Slejpner has been identified in one isolate (WBRS-90-9) both in 1991 field nurseries (Jones & Clifford, 1992) and in adult plant tests carried out under controlled environmental conditions in 1991 and 1992. Cultivars Zodiac and Hunter are susceptible to this isolate in seedling tests but their responses as adult plants are unknown, although spreader bed tests at the NIAB, Cambridge identify cv. Zodiac as being susceptible and cv. Hunter resistant.

Group 2 (WBR-2) Cultivars: Cultivars Fundin, Norman and Hobbit (WBR-2) were susceptible to both isolates, although isolate WBRS-91-61 (WBV-6) was not compatible with these cultivars at the high temperature regime (25°C) in 1991 seedling tests.

Other WBR Groups: Cultivar Sappo (WBR-3) was susceptible to both isolates, although neither isolate was identified as carrying the corresponding virulence in seedling tests. Cultivar Halberd (WBR-4) expressed resistance in both nurseries as did cvs Baldus and Canon. Previous years seedling tests indicate that these two latter cultivars carry resistance factor WBR-3 but also have additional resistance to WBV-3 pathotypes which is expressed only at the adult plant stage of growth. The race specific resistance of cv. Avalon was not overcome by isolates WBRS-91-61 and WBRS-91-66.

A group of susceptible cultivars comprising Riband, Mercia, Galahad, Talon and Armada expressed a range of quantitative responses to the isolates of a non-specific nature with cv. Riband being relatively resistant and cvs Talon and Armada highly susceptible. The spring wheat cvs Tonic and Alexandria appear to carry a specific resistance effective against isolate WBRS-91-61 (WBV-6).

The remaining winter and spring wheat cultivars expressed high levels of resistance to the two isolates in the field, although adult plant tests carried out under controlled environmental conditions have identified virulence to cv. Hussar. This cultivar was susceptible at the low temperature regime (10°C) only to isolate WBRS-90-9. This isolate also infected cv. Hussar in spreader bed tests at the NIAB, Cambridge. In adult plant field tests, at the WPBS, Aberystwyth in 1991, cv. Hussar had shown very low levels of rust infection (0.2%) to the same isolate.

Further tests are needed to identify the specific resistances carried by many of the wheat cultivars: information necessary for the cultivars' deployment in diversification schemes.

REFERENCE

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.

Table 6. Reactions of winter and spring* wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1992

Cultivar (NIAB rating)		WBR factor	WBRS-91-66 (WBV-1,2,6)		WBRS-91-61 (WBV-6)	
Clement		1	21		3	
Apollo	(4)		14		2	
Haven	(3)	1+?	12		2	
Hornet			9	MS	1	MS
Beaver	(4)		7		0.5	
Admiral	(5)		5	MS	1	MS
Slejpner		1+APR	0		0	
Zodiac			0		0	
Hunter	(8)		0		0	
Fundin		2	25		18	
Hobbit			18		8	MS
Norman	(6)		12	MS	8	MS
Sappo*		3	13		11	
Canon*	(8)	3+	1		2	
Baldus*	(8)		0		0	
Halberd*		4	1	MS	Trace	MS
Huntsman		5	29		24	
Sabre		7	Trace		Trace	
Sterna			0.2		Trace	
Ranger		8	4		Trace	
Kinsman			5		0.1	
Avalon		9	1		0	
Riband	(4)		13	MS	11	MS
Mercia	(5)		18		23	
Galahad			21		19	
Armada			29		25	
Talon			29		33	
Tonic*	(3)		15		1	
Alexandria*	(3)		8		2	
Torfrida	(8)		0		0	
Estica			0		0	
Genesis			0		0	
Brigadier	(8)		0		0	
Axona*	(9)		0		0	
Concerto*			0		0	
Promessa*			0		0	
Hereward	(8)		Trace		0	
Hussar	(6)		Trace		0	
Pastiche			Trace		Trace	
Spark	(4)		0.5		0	
Cadenza			0.5		0.1	
Rascal*			4	R	Trace	R

Mean of 3 replicates, 2 assessment dates
All reaction types susceptible unless stated
MS = mixed susceptible; R = resistant
( ) NIAB rating; 1 = susceptible; 9 = resistant

BROWN RUST OF WHEAT - ADULT PLANT TESTS AT NIAB, CAMBRIDGE

A. G. Mitchell

National Institute of Agricultural Botany, Cambridge

The results of adult plant tests with four isolates of wheat brown rust in spreader beds at NIAB are summarised in Table 1. The tests were carried out as part of the Recommended List programme, funded by the Home-Grown Cereals Authority.

WPBS-90-9 was isolated in 1990 from cultivar Avalon in Spalding, Lincolnshire, and shows some virulence for the adult plant resistance of Slejpner (Jones, Clifford and Willoughby 1992). Assessments of brown rust in NIAB trials in 1992 indicate that isolates with similar virulence are becoming more widespread. WPBS-91-65 was isolated in 1991 from cultivar Pastiche in Grantchester, Cambridge, and WPBS-91-67 was isolated in 1991 from cultivar Virtue at PBI, Cambridge. Pastiche and Virtue have different uncharacterised adult plant resistances which are being used in breeding programmes. These are the first isolates with virulence for Pastiche or Virtue.

Table 1. *Reactions of winter wheat cultivars to isolates of* Puccinia recondita *in spreader beds at NIAB in 1992*

	% Infection with *Puccinia recondita**			
Cultivar	WPBS-87-7	WPBS-90-9	WPBS-91-65	WPBS-91-67
Apollo	0.2	0.5	18	9
Haven	17	17	14	13
Beaver	12	17	7	8
Admiral	1	0	16	8
Zodiac	0	12	1	0.1
Hunter	0	0	0	0
Avalon	21	28	16	25
Riband	10	2	16	14
Mercia	10	0	0.8	7
Talon	21	19	19	26
Torfrida	0	0	0	0
Estica	0	0	0	0
Genesis	0	0.2	0	0
Brigadier	0	0	0	0
Hereward	0	0.5	0	0
Hussar	0	5	0	0
Pastiche	0.2	0	16	1
Spark	5	11	2	12
Cadenza	1	10	5	7
Virtue	0	0	0	5

* Mean of two replicates assessed twice

The results show that some currently recommended cultivars are susceptible to these new isolates of brown rust. In particular, Apollo and Admiral are susceptible to WPBS-91-65 and WPBS-91-67, Zodiac and Hussar are susceptible to WPBS-90-9, and Spark and Cadenza are susceptible to WPBS-90-9 and WPBS-91-7. This has resulted in lower ratings for resistance to brown rust for these varieties on the U.K. Recommended List of Cereal Varieties.

Jones, E.R.L., B.C. Clifford and D.B. Willoughby (1992). Brown rust of wheat. *U.K. Cereal Pathogen Virulence Survey Annual Report*, pp 19-23.

MILDEW OF BARLEY

A. G. Mitchell and S. E. Slater

National Institute of Agricultural Botany, Cambridge

The barley mildew population has continued to increase in complexity in response to widespread use of specific resistances in winter and spring barley cultivars. Most barley mildew virulence factors and combinations of factors corresponding to resistance factors used in barley cultivars in the UK were recorded at high frequencies. Virulence for BMR9 (*mlo*) was not detected, and this gene remains effective.

INTRODUCTION

Surveys of barley powdery mildew carried out over recent years (Mitchell and Slater 1991, 1992) have detected a high frequency of the virulence factors and combinations of virulence factors matching the specific resistance genes used in commercial barley cultivars. The exception is barley mildew resistance factor (BMR) 9, controlled by the *mlo* resistance gene, which has remained effective in the UK since it became available in the spring barley cultivar Atem in 1980.

The 1992 survey continued with the aims of:

1. Monitoring changes in the frequencies of virulence factors and combinations of virulence factors matching the specific mildew resistances in commercial cultivars.

2. Determining the specific resistances of new cultivars.

3. Estimating the frequencies of virulence combinations for the compilation of the variety diversification scheme.

METHODS

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

Isolates from infected leaves were mostly from variety trials plots at 9 sites:

Bridgets, Hampshire	7 isolates	Bangor-on-Dee, Clwyd	30 isolates
Wye, Kent	9	Headley Hall, Yorkshire	41
NIAB, Cambridge	20	Cockle Park, Northumberland	12
Spalding, Lincolnshire	16	Elgin, Morayshire	4
Harper Adams, Shropshire	26		

Total 165 isolates

The source cultivars were:

Winter cultivars			
Magie (BMR2)	1 isolate	Manitou (BMR8)	1
Torrent (BMR3)	1	Fakir (BMR2,8)	13
Firefly (BMR1,2,5)	13	2 cultivars of unknown	4
Fighter (BMR2,6c)	6	specific resistance	
Spring cultivars			
Triumph (BMR6b,6c)	6 isolates	Delita, Camargue (BMR10)	17
Blenheim (BMR5,6c)	6	Nugget, Tyne (BMR4,10)	8
Dove, Vintage (BMR7)	14	Omega (BMR6c,10)	10
Decor, Chad (BMR6c,7)	11	Shirley, Goldie, Felicie, 39	
Derkado, Forester,		Vodka (unknown resistance)	
Hart (BMR9)	9		

An additional 35 samples of infected leaves failed to produce viable isolates of mildew.

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

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

Table 1. *Differential cultivars used to determine virulence factors in isolates of barley mildew in 1992.*

BMR group	European code	Resistance gene	Cultivar
0	0	None	Golden Promise
1b	Ra	*Mlra*	Igri *
1a,1b	Ha, Ra	*Mlh, Mlra*	Astrix
2a	We	*Mlg*	Goldfoil *
2a, 2b	We	*Mlg, Ml(CP)*	Zephyr
3	Sp	*Mla6, Mla14*	Midas
4	La	*Ml(La)*	Lofa Abed
5	Ar	*Mla12*	Hassan
6a	Kw	*Mlk*	Hordeum 1063 *
6b	Ly	*Mla7*	Porter
6a,6b	Kw, Ly	*Mlk, Mla7*	Ark Royal
6c	Ab	*Ml(Ab)*	Lotta (SV83380)
6b, 6c	Ly, Ab	*Mla7, Ml(Ab)*	Triumph
5, 6c	Ar, Ab	*Mla12, Ml(Ab)*	Natasha
7	Al	*Mla1*	Tyra
6a, 8	Kw, MC	*Mlk, Mla9*	Simon
9	Mlo	*mlo*	Apex
10a	Ru	*Mla13*	Digger
9?	Mlo	*mlo* ?	Forester
		Unknown	Shirley

* Isolates were tested on Igri, Goldfoil and Hordeum 1063 only when tests on other differential cultivars did not identify all virulence factors.

RESULTS

Virulence Frequencies

The frequencies of BMV1a, 1b, 2a, 2b, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10 in the sample from infected leaves (leaf sample) and the random samples of airborne spores are given in Table 2. In addition to the complete data, the results for the leaf sample are given excluding those virulences in individual isolates which match the resistances in the host cultivar (unnecessary virulence frequencies). This should reduce the influence of host resistance in selecting virulences from the pathogen population.

The virulence factors were all recorded at high frequencies, particularly where the corresponding resistances have been used in commercial cultivars for some time. None of the 9 isolates from cultivars with BMR9 (*mlo*) were virulent on their host cultivar.

The frequencies of BMR5, 8 and 10 showed a slight increase compared to 1991, reflecting increasing popularity of cultivars with the corresponding resistances, particularly Puffin (BMR1,2,5), Blenheim (BMR5,6c), Manitou (BMR8), Pipkin (BMR10) and Tyne (BMR4,10). The frequency of BMR10 showed the largest increase, especially when BMR10 was unnecessary for virulence on the host cultivar. Only BMR7, 8 and 10 were recorded at a lower frequency when unnecessary virulences were compared with the complete data. This suggests that there is some degree of host selection for these virulence factors, but not for other virulences recorded at higher frequencies.

Table 2. *Frequency of virulence factors in isolates of barley mildew from infected leaves (leaf sample) and in random samples of single colony isolates formed by airborne spores in 1992.*

	Frequency of virulence factors (%)					
	Leaf sample		Random samples of airborne spores			
			NIAB, Cambridge			
Virulence factor	All data	Unnecessary virulence*	March	October	ADAS, Cardiff	SCRI, Dundee
1a	78	79	87	77	79	57
1b	100	100	100	100	98	98
2a	100	100	99	97	96	98
2b	99	98	98	97	90	98
3	26	20	31	16	39	48
4	39	34	15	5	27	30
5	77	76	71	62	77	76
6a	79	85	77	75	77	67
6b	86	86	82	76	83	35
6c	70	59	77	73	69	67
7	24	9	3	7	21	0
8	38	28	15	25	15	22
10	49	32	41	46	12	46
Number of isolates	165	165	100	101	51	45

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

Frequencies of virulence factors in the random samples of airborne spores from Cambridge and Cardiff were mostly similar, allowing for the small size of the Cardiff sample. BMR4 and BMR7 were recorded at higher frequencies in the Cardiff sample, and BMR10 at a lower frequency compared to the Cambridge samples. In 1991 a higher frequency of BMR10 was recorded in the sample from Dundee compared to leaf samples or random samples of airborne spores from England. However, this difference was not apparent in 1992, as the frequency of BMR10 has increased in England over the past few years. This reflects the increase in popularity of the winter cultivar Pipkin in England over this period.

Complexity of Isolates

The number of virulence factors carried by isolates in the leaf sample and random samples of airborne spores are given in Table 3. As in 1991, the majority of isolates in the leaf sample carried 7 or more virulence factors. The data for the random samples of airborne spores suggest an increase in the number of virulence factors carried in the absence of any host selection, especially in the samples from Cambridge.

Table 3. *Number of virulence factors (BMV1a, 1b, 2a, 2b, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10) carried by isolates of barley mildew in 1992.*

	Frequency of isolates with each no. of virulence factors (%)				
		Random samples of airborne spores			
		NIAB, Cambridge		ADAS,	SCRI,
No. of BMV factors	Leaf sample	March	October	Cardiff	Dundee
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	2	2
4	0	0	1	4	2
5	0	2	5	6	13
6	5	4	15	16	29
7	13	24	22	37	33
8	28	42	37	25	13
9	28	21	16	10	4
10	18	7	4	0	2
11	7	0	1	0	0
12	1	0	0	0	0
13	0	0	0	0	0
No. of isolates	165	100	101	51	45

Frequencies of Pathotypes

The frequencies of the most common pathotypes in the samples are given in Table 4. These common pathotypes were recorded in each of the Cambridge samples, but some were absent from the small samples from Cardiff and Dundee. The same pathotypes have been recorded at high frequencies in previous years. Most other pathotypes were detected only once in each sample.

The first three pathotypes listed in Table 4 all carry BMR5, 6b and 6c in combination with other virulence factors, and would be able to infect many widely grown winter barley cultivars, and Blenheim, the most popular spring .mt 0.5" cultivar. The other common pathotypes all carry BMR10 in addition to other virulences, and in general isolates carrying BMR10 tended to be the more complex, with a greater number of virulence factors.

Table 4. *Frequencies of the most common barley mildew pathotypes in 1992, defined by BMV 1a, 1b, 2a, 2b, 3, 4, 5, 6a, 6b, 6c, 7, 8 and 10.*

Pathotype *	Frequency of pathotype (%)				
		Random samples of airborne spores			
		NIAB, Cambridge		ADAS,	SCRI,
	Leaf sample	March	October	Cardiff	Dundee
5 6b 6c	3	5	4	16	4
5 6a 6b 6c	3	13	15	32	16
3 5 6b 6c	3	7	4	8	0
6a 6b 10	1	6	3	0	0
6a 6b 6c 10	1	3	3	8	0
5 6a 6b 6c 10	3	5	4	0	4
6a 6b 8 10	3	2	2	4	0
6a 6b 6c 8 10	1	5	3	0	0
4 6a 6b 8 10	1	0	0	0	0
Total no. of pathotypes	83	46	50	27	30
No. of isolates	165	100	101	51	45

* All of these pathotypes also carried BMV 1a, 1b, 2a and 2b.

Resistance Factors in New Cultivars

The resistance factors in cultivars currently included in the Barley Mildew Variety Diversification Scheme are listed in Table 5.

CONCLUSIONS

1. The barley mildew population has continued to increase in complexity in response to widespread use of specific resistances in winter and spring barley cultivars. Consequently, most combinations of specific resistance factors are largely ineffective, although there is some indication that new winter cultivars have better background resistance.

2. BMR 9 (*mlo*) remains effective, and is now present in many popular spring barley cultivars.

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

BMR 0		**BMR 8**		**BMR 2,4**	
Halcyon	(W)	Manitou	(W)	Golf	(S)
Golden Promise	(S)				
		BMR 9		**BMR 2,6c**	
BMR 1b		Alexis	(S)	Fighter	(W)
Bambi	(W)	Atem	(S)		
Bronze	(W)	Chariot	(S)	**BMR 4,6a,6b**	
Chestnut	(W)	Dandy	(S)	Klaxon	(S)
Clarine	(W)	Derkado	(S)		
Gaulois	(W)	Forester?	(S)	**BMR 4,10**	
Igri	(W)	Hart	(S)	Tyne	(S)
Intro	(W)			Nugget	(S)
Karisma	(W)	**BMR 10**			
Posaune	(W)	Dallas	(S)	**BMR 5,6c**	
Pastoral	(W)	Delita	(S)	Blenheim	(S)
Plaisant	(W)	Pipkin	(W)	Corniche	(S)
Sprite	(W)	Sherpa (+?)	(S)	Prisma	(S)
Swift	(W)	Vodka (?+4)	(S)		
				BMR 6b,6c	
BMR 1a,1b		**BMR 1a, 5**		Triumph	(S)
Target	(W)	Willow	(W)		
				BMR 6c,7	
BMR 2		**BMR 1a,2,5**		Chad	(S)
Blanche (?+1b)	(W)	Puffin	(W)	Decor	(S)
Frolic	(W)	Firefly (+1b)	(W)		
Gypsy	(W)			**BMR 6c, 8**	
Magie (+1b)	(W)	**BMR 1a,2**		Nomad	(S)
Melusine (+1b)	(W)	Panda	(W)		
				BMR 6c,10	
BMR 6b		**BMR 1,2,3**		Camargue	(S)
Marinka	(W)	Kira	(W)	Omega	(S)
		Torrent	(W)		
BMR 7				**UNKNOWN**	
Dove	(S)	**BMR 2,8**		Felicie	(S)
Platoon	(S)	Fakir (?+1b)	(W)	Goldie	(S)
Vintage	(S)			Shirley	(S)

(W) winter cultivar, (S) spring cultivar

MILDEW OF BARLEY IN NORTHERN IRELAND

P.C. Mercer

Plant Pathology Research Division, Department of Agriculture, Northern Ireland

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

Table 1. Source of mildew isolates tested in 1992

BMR group	Isolate source	No. isolates
0	Pastoral	2
2	Gypsy	1
	Blanche	1
7	Chad	8
9	Dandy	2
4 + 10	Tyne	9
5 + 6c	Blenheim	1
	Prisma	1
1 + 2 + 3	Kira	5
	Torrent	4
1 + 2 + 5	Puffin	1
	Firefly	1

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

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

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

The most commonly sown barley cultivars in N. Ireland in the previous season 1990/91 are shown in Table 3.

Table 3. Percentage use of barley cultivars in N. Ireland (1990/91)

Spring cultivars		Winter cultivars	
Tyne	27	Pastoral	38
Dandy	25	Torrent	23
Blenheim	9	Kira	18
Escort	8	Gypsy	6
Nugget	7	Marinka	5

The frequency pattern of the single major genes 2,3,4 & 5 (Table 4) was more similar to that of 1990 than 1991. This suggests experimental variation rather than genuine shifts in frequency. It is probable that the safest comparisons are between patterns for individual years. On that basis the increase in recent years of the combined virulences 6a + 6b and 6b + 6c appears to be levelling off. The frequency of BMV 7 was still relatively low, although nearly a quarter of the mildew isolates were from Chad (BMR 7). The frequency of BMV 8 appears fairly stable, although there are no popular cultivars carrying the corresponding resistance gene. The combined virulence BMV 3 + 4 appears to be declining, possibly following the demise of popular cultivars such as Goldmarker and Goldspear. BMV 4 + 5 may have increased slightly, while BMVs 4 + 6a and 4 + 6a + 6b have remained level. There is still no evidence of any marked virulence on BMR 4 + 9, although Dandy (BMR 9) was the second most popular cultivar. The frequency of BMV 10 which had been increasing over the last few years appears to have levelled off. BMV 4 + 10 was tested for the first time in 1992 and showed a very low frequency, although Tyne was the most popular cultivar.

Table 4. Pathogenicity values for 1989 plus frequencies of virulence alleles from isolates collected from infected leaves from 1990- 1992.

Virulence	Pathogenicity values (1989)	Virulence frequencies (%) 1990	1991	1992
2	65	43	64	39
3	35	41	54	36
4	53	27	57	25
5	77	46	54	31
6a + 6b	42	48	57	31
6b + 6c	38	33	71	36
7	31	20	14	14
8	44	27	30	28
3 + 4	32	67	39	36
4 + 5	32	27	50	47
4 + 6a	37	50	50	44
4 + 6a + 6b	43	59	41	44
4 + 9	5	0	0	0
4 + 10	n.a.	n.a.	n.a.	3
10	n.a.	14	46	25

Differences with populations in Britain (Mitchell & Slater, 1993) probably reflect less complex populations in N. Ireland, due to differences in cultivar popularity. For example, although a cultivar with BMR 4 + 10 is currently popular in N. Ireland, the level of the corresponding virulence is low compared with Britain suggesting a period of "catching up". However, it is also possible that the UK mildew populations may have some direct effect through wind movements on those in N. Ireland .

Tests continued on the effectiveness of Baytan seed-treatment. Results (Fig. 1) showed a continuation of the trend towards increased resistance seen in recent years. This was particularly evident at full-rate and 1/3 rate. Results at 1/15 rate seem a little confusing, although there still appears to be a measure of control in all years with the exception of 1991.

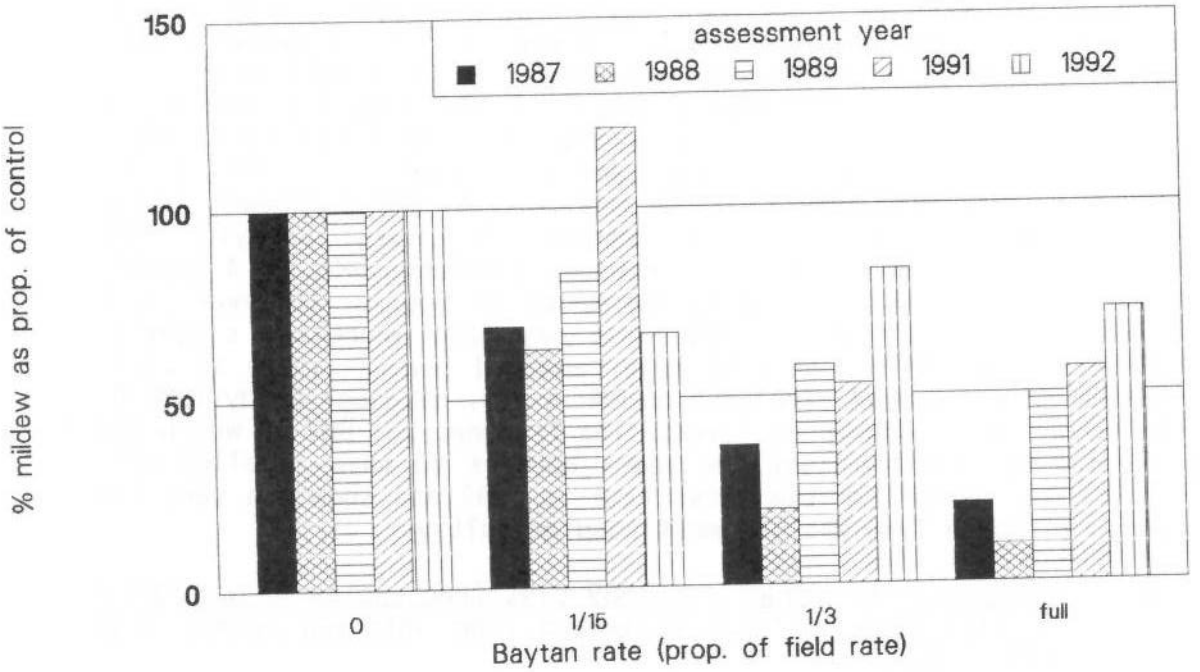

Fig. 1 Percentage of colonies of mildew growing on Baytan-treated seedlings as a proportion of those on untreated seedlings (n.a. = not available).

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YELLOW RUST OF BARLEY

M H Meadway and W C Hutton

National Institute of Agricultural Botany, Cambridge

Two isolates possessing BYV 1,2 were received during 1992.

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 tests with 1992 isolates

Two samples were received from North Yorkshire from two UK National list spring barley cultivars.

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

RESULTS

Virulence frequencies for 1977-1992 are shown in Table 2.

Table 2 Virulence factor frequency (%)

	'77	'78	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92
BYV 1	100	98	100	100	100	100	100	100	-	-	100	-	100	100	100	100
BYV 2	18	32	0	54	81	96	87	100	-	-	100	-	100	0	100	100
BYV 3≠	-	-	-	-	-	-	17	86	-	-	22	-	75	0	0	0
Number of isolates	27	44	1	56	52	25	30	7	0	0	9	0	4	1	1	2

≠ Not included in tests before 1983.

The 1992 isolates were virulent on the BYV 1 differentials Astrix and Atem and the BYV 2 differentials Bigo and Varunda.

REFERENCE

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BROWN RUST OF BARLEY

E.R.L. Jones and B.C. Clifford

AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station, Aberystwyth, Dyfed SY23 3EB, U.K.

Seedling tests confirmed the continuing high frequency of virulence to cv. Triumph in the brown rust population. Field isolation nurseries showed that a number of the winter barley cultivars carried resistance to the two introduced isolates. Cultivar/pathogen interactions within the spring barleys enabled the cultivars to be grouped on the basis of similarities in their patterns of response.

GLASSHOUSE SEEDLING TESTS WITH 1992 ISOLATES

One hundred and thirty-three samples of barley brown rust were received in 1992. This number included 90 sent from the ADAS Cereal Disease Survey. One hundred and twenty-six of the samples were from a range of winter barley cultivars, with only 7 samples coming from spring barleys. The samples received were from 5 ADAS regions of England and Wales (Table 1).

Table 1. Geographical location of 1992 barley brown rust samples

Location	Number of samples
England (ADAS region)	
East-central	50
East	38
South-west	30
West-central	9
North	4
Wales	2

Isolates of *Puccinia hordei* from 77 of the samples were cultured and tested on the standard set of 10 differential cultivars (Table 2).

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

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

Results

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

Table 3. Races and their frequencies identified from the 1992 isolates compared with the previous four years

Octal designation	BBV factors	Frequency				
		1988	1989	1990	1991	1992
1673	1,2,4,5,6,8,9,10	0.27	0.47	0.49	0.80	0.65
1653	1,2,4,6,8,9,10	0.57	0.18	0.12	0.07	0.25
673	1,2,4,5,6,8,9	0.16	0.35	0.39	0.07	0.02
1657	1,2,3,4,6,8,9,10	0	0	0	0.02	0.04
1677	1,2,3,4,5,6,8,9,10	0	0	0	0.04	0.04
Number of isolates		60	73	49	53	77

Two virulence combinations capable of overcoming the resistance carried by the differential cv. Ribari (BBR-3) were detected in 1992. Race octal 1657 was identified in three isolates cultured from infected leaf samples of the spring barley cultivars Alexis (2) and Triumph. Three other isolates also shown to carry virulence to BBR-3 were identified as race octal 1677 - a widely virulent race which fails only to overcome the resistance of the differential cv. Cebada Capa (Pa7). The presence of virulence to cv. Ribari in the brown rust population, albeit at a low level, is unexpected as none of the winter and spring barley cultivars in the current NIAB "Recommended Varieties of Cereals" leaflet are known to carry the corresponding resistance gene. The frequency of virulence to the differential cv. Triumph (BBR-10) was again at a high level (0.98) in 1992.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Twenty-seven winter and 31 spring barley cultivars were sown in each of two nurseries in the 1991-92 season. One was inoculated with race octal 1653 and the other with race octal 677. A third nursery, sown with spring barley cultivars only, was inoculated with race octal 11.

Race octal	BBV factors
1653	1,2,4,6,8,9,10
677	1,2,3,4,5,6,8,9
11	1,4

Results

High levels of rust built up on the spreader cultivars within the winter and spring barley nurseries providing a ready source of inoculum for the test cultivars. Isolates of *P. hordei* cultured from samples taken from within each nursery during early June indicated contamination of the nurseries with Triumph-virulent pathotypes. The contamination appeared to be less severe in 1992 than in recent seasons.

The winter barley cultivars displayed a range of quantitative responses within both nurseries with cultivar rankings between nurseries following a similar pattern (Table 4). Higher levels of disease were apparent on the susceptible cultivars within the nursery inoculated with race octal 1653 confirming previous observations that the currently grown winter barley cultivars are more readily infected with Triumph-virulent isolates. A few of the cultivars expressed resistance to both isolates.

The spring barleys have been grouped, as in 1991, on the basis of similarities in their patterns of response to the 3 isolates (Table 5). The highly susceptible cvs Midas and Golden Promise are not known to carry any resistance.

Cultivars Hart, Dandy and Armelle are grouped with cv. Triumph (BBR-10) on the basis of the similarities in their patterns of response to the three isolates. Their pedigrees indicate that they do not share a common resistance with cv. Triumph, the former two cultivars being crosses of cvs Atem and Egmont suggesting that any resistance may be derived from cv. Vada.

Cultivars Camargue and Alexis have been placed in Group 3 with Forester and Dallas, although their pedigrees suggest that they should carry the resistance BBR-10 from cv. Triumph. They have been grouped separately from cv. Triumph on the basis of their expression of a more resistant response to the isolates.

Group 4 cultivars displayed a susceptible reaction of a mixed type to the 3 isolates, but did not show the high levels of infection of cvs Midas and Golden Promise. The group is typified by cv. Vada which carries a non-specific resistance.

The resistance of cultivars in Group 5 was effective against all the isolates although quantitative differences in levels of infection were apparent.

Cultivar Simon (Group 6) was resistant to race octal 1657 and race octal 11, but susceptible to race octal 677 which carries the corresponding virulence gene (BBV-3).

Table 4. Percent infection* of winter barley cultivars with specific isolates of *P. hordei* Otth. in field isolation nurseries in 1992

Winter Cultivar (NIAB rating)		Race octal 1653 (BRV-1,2,4,6,8,9,10)		Race octal 677 (BRV-1,2,3,4,5,6,8,9)	
Clarine	(4)	33		18	
Marinka	(6)	32		20	
Torrent	(4)	32		17	
Posaune	(6)	29		12	
Blanche		27		17	
Pipkin	(6)	26		19	
Target	(5)	25		19	
Gypsy		24		12	
Kira	(6)	23		18	
Frolic	(7)	23		10	
Melusine		21		19	
Manitou	(5)	21	MS	12	MS
Pastoral	(6)	20		10	
Halcyon	(7)	19		13	
Bronze	(7)	18		8	
Magie	(5)	18		7	MS
Gaulois	(6)	18		6	
Fakir		17		7	MS
Fighter	(7)	15		12	
Chestnut		14		6	
Bambi		11		4	MS
Firefly	(8)	7	MS	8	MS
Karisma		7	MS	3	MS
Intro	(8)	6	MS	5	MS
Puffin	(8)	2	MS	2	MS
Willow	(8)	2	MS	1	MS
Swift		1	MS	2	MS

* Mean of 4 replicates, 3 assessment dates
( ) NIAB rating: 1 = susceptible, 9 = resistant
All reaction types susceptible unless stated
MS = mixed susceptible

Table 5. Percent infection* of spring barley cultivars with specific isolates of *P. hordei* Otth. in field isolation nurseries in 1992

Spring cultivar (NIAB rating)		Race octal 1653 (BRV-1,2,4,6,8,9,10)		Race octal 677 (BRV-1,2,3,4,5,6,8,9)		Race Octal 11 (BRV-1,4)	
Midas		37		28		28	
Golden Promise		35		27		23	
Blenheim	(4)	31		16	MS	13	MS
Prisma	(4)	31		13	MS	10	MS
Hart	(4)	28		22		15	MS
Dandy	(3)	27		21		15	MS
Triumph	(5)	21		5	MS	5	MS
Armelle		19		16	MS	12	MS
Nomad	(6)	15		17	MS	18	MS
Camargue	(6)	22		5	MR	4	MR
Forester	(7)	15	MS	9	MR	8	MR
Alexis	(7)	13	MS	22	MR	5	MR
Dallas		5	MS	2	MR	2	MR
Chariot	(5)	17	MS	19	MS	17	MS
Nugget		14	MS	16	MS	17	MS
Felicie	(7)	13	MS	17	MS	6	MS
Vada		10	MS	11	MS	12	MS
Shirley		9	MS	10	MS	8	MS
Vodka		8	MS	14	MS	2	MS
Platoon		8	MS	13	MS	9	MS
Derkado	(7)	9	MR	4	R	2	R
Decor	(7)	8	MR	7	MR	4	MR
Tyne	(7)	7	MR	7	MR	13	MR
Chad	(8)	7	MR	5	R	5	R
Vintage		7	R	5	R	2	R
Delita		6	MR	2	MR	4	MR
Dove		5	MR	13	MR	11	MR
Corniche		2	MR	0.5	MR	0.05	MR
Goldie		1	MR	3	R	Trace	R
Bianka		Trace	R	1	R	Trace	R
Simon		1	MS	23		0.1	MS

* Mean of 4 replicates, 3 assessment dates
( ) NIAB rating: 1 = susceptible, 9 = resistant
All reaction types susceptible unless stated
MS = mixed susceptible, MR = mixed resistant, R = resistant

RHYNCHOSPORIUM OF BARLEY

E. R. L. Jones and B. C. Clifford

AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station, Plas Gogerddan, Aberystwyth, Dyfed SY23 3EB, U.K.

Virulence to cv. Osiris (BRR-6) was found in 2 isolates. One, identified as race octal 167, carried a previously unidentified virulence combination (BRV-1,2,3,5,6,7). Several winter barley cultivars displayed good levels of resistance to the pathogen in field nurseries. The resistance of the spring barley cv. Digger (BRR-?) remains effective.

SEEDLING TESTS WITH 1992 ISOLATES

Forty-one leaf samples infected with *Rhynchosporium* were received in 1992, together with 4 agar cultures from the MAFF/ADAS winter barley disease survey. The leaf blotch samples were from a range of winter (18) and spring (22) barley cultivars. One sample was received from infected couch grass (*Elymus repens*). The geographic origins of the samples are given in Table 1.

Table 1. Geographic origin of *Rhynchosporium* samples received in 1992

Location	Number of samples
England (ADAS region)	
East-central	21
East	7
South-west	2
West-central	1
Wales	7
Scotland	3

Thirty 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

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

Table 3. Virulence factor combinations identified from the 1992 survey

No. of isolates	Differential cultivars in fixed linear order							Race octal
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
9	0	0	0	1	1	0	0	14
8	1	0	0	1	1	1	1	117
4	1	0	0	1	1	0	0	114
3	0	0	0	1	1	1	1	17
2	0	0	0	0	1	0	0	4
1	0	0	0	0	0	0	0	0
1	1	1	1	0	1	1	1	167
1	1	1	1	1	1	0	0	174
1	1	0	1	1	1	0	0	134

1 = susceptible 0 = resistant

Two isolates carried virulence to cv. Osiris (BRR-6). One, Rs-92-12, isolated from a leaf sample of cv. Pipkin (BRR-5) was identified as race octal 174. This virulence combination (BRV-3,4,5,6,7) was first detected in two isolates, also sampled from cv. Pipkin, in 1990. The second isolate, designated race octal 167, lacks virulence only to cv. Igri (BRR-4). This previously unidentified virulence combination (BRV-1, 2,3,5,6,7) was sampled from the winter barley cv. Fighter grown at the same trial site in Norfolk as isolate Rs-92-12. Since the initial identification of virulence (BRV-6) to cv. Osiris in 1985, all six naturally infected leaf samples of the pathogen identified as carrying this virulence have originated in the east of England, although none of the currently-grown cultivars are known to carry the corresponding resistance factor BRR-6. BRV-6 has been found in various combinations with other virulence factors, but all the Osiris-virulent isolates have also carried virulence (BRV-5) to cv. La Mesita.

Frequencies of individual virulences (Table 4) fluctuate over the years, although those matching the resistances of cv. Athene (BRR-3) and cv. Igri (BRR-4) remain at high levels as does that for cv. Pirate (BRR-7). Those for cvs Astrix and Armelle fluctuate around the 0.50 level and, at present, BRV-5 and BRV-6 (cvs La Mesita and Osiris) are at low levels.

Table 4. Frequences of individual virulences, 1988-1992

	BRV-						
	7	6	5	4	3	2	1
1988	0.81	0	0	0.98	0.98	0.19	0.19
1989	0.54	0.08	0.23	0.92	0.92	0.62	0.62
1990	0.54	0.23	0.30	0.76	0.92	0.23	0.23
1991	0.28	0	0	0.52	0.74	0.22	0.22
1992	0.50	0.07	0.10	0.86	0.97	0.40	0.40

These interpretations should be treated with caution as the sampling procedure is not random. However, it is of interest and concern that virulence to all resistances has been detected and complex combinations of virulence occur frequently as in race octal 117. The detection of races octal 167 and 174 is also of concern.

The resistance of the spring barley cv. Digger remains effective although several isolates induced low infection levels (2%-5%). No samples were received from this cultivar.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Thirty-three winter and 32 spring barley cultivars were sown in each of 2 nurseries in the 1991-92 season. One nursery was artificially inoculated throughout the season with isolate Rs-85-50. This widely virulent isolate carries BRV factors 1,2, 3,4,5,6 (race octal 77). The second nursery was grown alongside and received inoculum from a *Rhynchosporium* disease nursery used to screen barley material and which is infected naturally. Leaf samples taken from the nursery in April and June were tested on seedlings of the set of differential cultivars. The isolate cultured from the infected leaves collected in April was identified as race octal 0, although cvs Igri and Pirate displayed low levels of infection. A culture prepared from leaves taken at the second sampling date was identified as race octal 4.

Results

Winter barleys: High levels of disease built up on the susceptible winter barley cultivars in both nurseries (Table 5). The cultivars displayed a range of quantitative responses within both nurseries with cultivar rankings between nurseries following a similar pattern (Table 4). Cultivar Igri (BRR-4) was susceptible within the nursery infected naturally, although in glasshouse seedling tests it had been mainly resistant to isolates cultured from infected leaves sampled from the nursery. Cultivar Pipkin (BRR-5) was also resistant in these seedling tests but was susceptible (16% leaf area infected) in the field. This cultivar, like cv. La Mesita (BRR-5) from which it derives its resistance, is more susceptible at the adult plant stage of growth (Clifford and Jones, 1982) even to isolates not carrying the corresponding virulence gene. Isolate BRS-85-50 failed to infect cvs Igri (BRR-4) and Astrix (BRR-2) despite carrying the corresponding virulence factors. Several of the winter barleys displayed good levels of resistance.

Spring barleys: Reasonable levels of *Rhynchosporium* infection were achieved on the susceptible spring barleys (Table 6) grown in the naturally infected nursery where the cultivars expressed quantitative differences in susceptibility to the pathogen. Disease levels were very low within the nursery inoculated with isolate Rs-85-50 of the widely virulent race octal 77. This isolate failed to infect cvs Armelle (BRR-1), La Mesita (BRR-5) and Osiris (BRR-6) despite carrying the corresponding virulence factors.

REFERENCE

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

Table 5. Percent infection* of winter barley cultivars in *Rhynchosporium* isolation nurseries in 1992

Cultivar (NIAB rating)		Naturally infected (see text)	RS-85-50 (BRV-1,2,3,4,5,6)
Maris Otter		46	36
Willow	(4)	38	28
Posaune		30	5
Swift		24	7
Intro	(6)	23	9
Bronze	(6)	21	3
Frolic	(8)	19	3
Athene		18	7
Blanche		17	9
Igri		17	2
Pipkin	(3)	16	20
Pastoral	(7)	12	2
Fighter	(6)	11	7
Gaulois	(8)	10	3
Puffin	(7)	5	4
Clarine		5	3
Halcyon	(7)	5	3
Kira	(8)	5	1
Magie		4	4
Karisma		4	2
Pirate		3	4
Bambi		3	2
Chestnut		3	1
Melusine		3	1
Gypsy		2	2
Torrent	(8)	2	2
Firefly	(8)	2	1
Marinka	(8)	1	1
Astrix		1	1
Target	(8)	1	0.5
Hoppel		1	0.1
Manitou	(8)	0.5	0.5
Fakir		0.1	0.5

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

Table 6. Percent infection* of spring barley cultivars in *Rhynchosporium* isolation nurseries in 1992

Cultivar (NIAB rating)		Naturally infected (see text)	RS-85-50 (BRV-1,2,3,4,5,6)
Forester	(3)	28	8
Derkado	(4)	25	2
Shirley		22	1
Chariot	(4)	17	3
Chad	(5)	16	5
Bianka		16	2
Goldie		16	2
Alexis	(4)	14	2
Tyne	(4)	12	4
Vodka		12	1
Decor	(6)	11	1
Platoon		11	1
Hart	(6)	10	2
Delita		9	1
Vintage		9	1
Camargue	(6)	8	1
Proctor		7	7
Prisma	(4)	7	2
Nomad	(5)	6	2
Dandy	(6)	6	1
Nugget		6	1
Dallas		6	1
Golden Promise		6	1
Felicie	(7)	3	0.5
Midas		6	0.5
Dove		6	1
Blenheim	(5)	4	0.3
La Mesita		4	2
Triumph	(5)	3	0.5
Osiris		3	0.1
Digger		0.5	0
Armelle		0.1	0

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

NET BLOTCH OF BARLEY

E.R.L. Jones and B.C. Clifford

AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station, Aberystwyth, Dyfed SY23 3EB, U.K.

Isolates carrying a range from 1 to 10 virulence factors were identified from the 1992 net blotch samples. Twelve isolates failed to produce a susceptible reaction on any of the seedling differential cultivars although they were compatible with several of the additional winter and spring barley cultivars included in the tests.

GLASSHOUSE SEEDLING TESTS WITH 1992 ISOLATES

Fifty-eight samples of net blotch were received from winter (54) and spring (1) barley cultivars. Three were of unknown origin. The samples were from 6 ADAS regions of England and Wales (Table 1).

Table 1. Geographical location of 1992 net blotch samples

Location	Number of samples
England (ADAS region)	
West-central	23
North	20
East	8
East-central	2
South-west	2
South	1
Wales	2

Spore suspensions of *Pyrenophora teres* Drechs. prepared from the samples were inoculated onto seedlings of the 13 differential cultivars. Cultivar Marinka was included in the tests together with 12 additional winter and spring barleys from the NIAB Recommended List and Recommended List Trials.

Results

Forty-six of the isolates were successfully tested. The frequencies of individual virulences corresponding to resistance factors in the differential cultivars together with virulence frequencies since 1984 are given in Table 2.

Table 2. Virulence frequencies corresponding to each differential cultivar (UK CPV Surveys 1984-1992)

Code Number	Cultivar	1984	1986	1988	1990	1992
1	C.I.5401	0	0	0.28	0	0
2	C.I.6311	0.22	0.39	0.72	0.13	0.02
3	C.I.9820	0	0.04	0.28	0	0
4	C.I.739	0.33	0.61	0.50	0.31	0.13
5	C.I.1243	0.44	0.57	0.39	0.13	0.09
6	C.I.4795	0	0	0.33	0.13	0.04
7	C.I.4502	0	0	0.33	0.19	0.04
8	C.I.4979	0.44	0.50	0.56	0.38	0.04
9	Proctor	0.55	0.79	0.56	0.56	0.52
10	Code 65(W)	0	0	0.72	0.31	0.09
11	C.I.9518(W)	1.00	0.96	0.39	0.88	0.56
12	Tenn.61-119(W)	0.44	0.57	0.89	0.75	0.50
13	C.I.9214	0	0	0.56	0.19	0.04
No. of isolates tested		9	28	18	15	46

W = winter cv.

The virulences identified occurred in various combinations, giving a range from a single virulence factor in some isolates to more complex combinations comprising of up to 10 virulence factors. Twelve of the isolates failed to induce a susceptible reaction on any of the differential cultivars although several of the additional barleys included in the seedling tests were susceptible. Of these isolates, 11 were cultured from a set of 22 heavily infected winter barleys sampled at the NIAB Regional Trial Centre, Harper Adams Agricultural College, Salop. The most widely virulent isolate identified from this site was cultured from leaves of cv. Swift and carried virulence factors 4,5,6,7,8,9,11 and 12. Cultivar Marinka, together with the winter and spring barleys (Table 4) included in the seedling tests, were susceptible to this isolate, designated BNS-92-31. Virulence to cv. Marinka was identified in 20 of the isolates tested in 1992. The frequency in the pathogen population to this cultivar has shown a decline since it was first detected in 1987, although this trend was reversed in 1992 (Table 3).

Table 3. Frequency of virulence to cv. Marinka

UK CPV Survey Year	Frequency	No. of samples tested
1987	0.79	24
1988	0.67	18
1989	0.54	14
1990*	-	-
1991	0.25	15
1992	0.43	46

* Only 3 samples tested

The winter and spring barley cultivars displayed a range of responses to the 46 isolates tested in 1992 (Table 4). Cultivar Target was susceptible to 89% of the isolates whereas the spring barley cvs Chariot and Chad displayed lower levels of susceptibility with 15% and 11% of isolates being compatible respectively.

Table 4. Frequencies of virulence of 1992 net blotch isolates to winter and spring barley cultivars

Cultivar		Frequency
Target	(W)	0.89
Torrent	(W)	0.83
Gypsy	(W)	0.70
Karisma	(W)	0.65
Platoon		0.65
Blanche	(W)	0.59
Vodka		0.54
Camargue		0.46
Goldie		0.37
Bianka		0.35
Chariot		0.15
Chad		0.11

W = winter cultivar

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

M.J. Adams

AFRC Institute of Arable Crops Research, Rothamsted Experimental Station, Harpenden, Herts, AL5 2JQ

Of 167 infected samples received in 1992, 53% contained barley yellow mosaic virus (BaYMV) and 60% barley mild mosaic virus (BaMMV). These proportions were similar to 1991 and, as in previous years, BaMMV was more frequent on malting cultivars (Halcyon, Pipkin and Puffin) whereas BaYMV predominated amongst cultivars used for feed. Three new "resistance-breaking" outbreaks of BaYMV were reported bringing the UK total to 15.

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 diseases are soil-borne, being transmitted by the root infecting fungus *Polymyxa graminis*, and persist in soil for many years. A single (recessive) gene 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. Japanese experience also suggests that races of the virus with different specific virulences may be expected. 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 especially in areas where winter barley is grown intensively and the diseases are most widespread.

METHODS

Leaves with symptoms, mostly received from MAFF CSL Harpenden Laboratory, were tested by enzyme-linked immunosorbent assay (ELISA) for the presence of both viruses as described by Adams (1990).

RESULTS AND DISCUSSION

167 positive samples were received in 1992, almost as many as in 1991. The proportions affected by the two viruses were very similar to the previous year (60% with BaMMV; 53% with BaYMV). For the 111 samples of which the cultivar was known, BaMMV was again predominant on the malting cultivars (Halcyon, Pipkin and Puffin). A small number of samples contained both viruses and three new outbreaks of "resistance-breaking" BaYMV were detected (Table 1). One apparent case of BaMMV on a resistant cultivar was investigated, but the infected plants were eventually identified as susceptible volunteers. A summary of the results for the six years of the survey (Table 2) demonstrates the consistent distribution of the viruses between the cultivar types. The 15 reports of "resistance-breaking" BaYMV are geographically distributed from Wiltshire to Cambridgeshire and Essex.

In an attempt to examine variation within "resistance-breaking" BaYMV isolates, a set of Japanese differential cultivars were planted on several naturally-infested sites in 1991/2 in collaboration with NIAB and ADAS. The cultivars suffered severe winter kill and only limited data were obtained but

Table 1. Mosaic virus samples from 1992, classified by cultivar

	Virus(es) detected		
	BaMMV alone	BaYMV alone	Both
Malting cultivars			
Halcyon	9	2	2
Pipkin	6	0	0
Puffin	30	3	8
Triumph (S)	0	0	1
Malting Subtotal	45	5	11
Feeding cultivars			
Alraune	0	1	0
Fighter	1	4	0
Frolic	0	2	0
Gypsy	0	1	1
Igri	1	0	0
Magie	0	3	0
Manitou	0	2	2
Marinka	2	11	2
Mimosa (R)	0	1	0
(Mixed)	0	1	1
Pastoral	2	4	1
Plaisant	0	4	0
Posaune	0	1	0
Target (R)	0	1	0
Torrent (R)	0	1	0
Feeding Subtotal	7	36	7
Not known	27	25	4
GRAND TOTAL	78	67	22

(R)= cultivar resistant to the common strain of BaYMV
(S)= spring cultivar sown in autumn

Table 2. Summary of mosaic virus samples 1987-1992

Cultivar type	Virus(es) detected		
	BaMMV alone	BaYMV alone	Both
Malting	137	12	21
Feeding (susceptible)	47	174	34
Feeding (resistant)	0	15	0
Not known	60	87	18
GRAND TOTAL	244	288	73

there were some suggestions of different disease patterns on the different sites. These investigations are being continued.

REFERENCE

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

MILDEW OF OATS

E.R.L. Jones and B.C. Clifford

AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station, Aberystwyth, Dyfed SY23 3EB, U.K.

Virulence (OMV-4) to the resistance derived from *Avena barbata*, which increased rapidly in the oat mildew population from 1989 to 1991, showed a sharp decline in frequency (0.17) in 1992. It occurred solely in combination with OMV-1, 2 and 3 (Race 7). Race 5 (OMV-1,2,3) was the only other race identified from the 1992 samples.

SEEDLING TEST WITH 1992 ISOLATES

Forty-nine samples of *Erysiphe graminis avenae* were received from spring oat cultivars in 1992. Isolates were successfully cultured from 42 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. The frequency of occurrence of the various virulences detected in 1992 compared with previous years are given in Table 3.

Isolates identified as race 7 (OMV-1,2,3,4) were at a reduced frequency (0.17) in 1992, reversing the pattern observed since 1989. This virulence combination, which is able to overcome all resistances, including that derived from *Avena barbata*, was the most prevalent (73%) in 1991. The less complex race 6 (OMV-1,2,4) which also carries virulence to this resistance, but which has been at a much lower frequency in the population than race 7, was not detected. The rapid increase in the numbers of isolates carrying OMV-4 followed by the decline in 1992 is difficult to explain as varieties carrying the corresponding resistance (OMR-4) have not been grown commercially in the UK. A large number of samples did give a type 2 reaction (moderate sized pustules with sporulation and some chlorosis and/or necrosis, but classified as resistant) on the differential cultivar Cc 6490 (a translocation line of *Avena barbata*).

The remaining isolates were all identified as race 5 (OMV-1,2,3) which was the prevalent race from 1984 to 1990.

Table 2. Locations and cultivars from which viable mildew samples were received in 1992 with virulences for each sample

Locations	Cultivars	Virulence combination (OMV-)
ENGLAND (ADAS Region)		
North		
Cockle Park, Northumberland	Dula, Matra, Valiant, Rhiannon, Keeper, Rollo, Melys, Semu 3767, 80/141/1, LP 8822, SU 8652	1,2,3
	Leanda, LP 8822, AS/2/067/88	1,2,3,4
East Central		
Headley Hall, North Yorkshire	Aberglen, Melys, Valiant, Odin, Dula, Rhiannon, Keeper	1,2,3
South		
Codford, Wiltshire	Dula	1,2,3
WALES		
Trawsgoed, Dyfed	Semu 3767, WW 17895, LP 8925 Keeper, Aberglen, Matra, 10026 Cn, 80/141/1, SV 86592, Melys, 10352 Cn, Rollo	1,2,3
	LP 8822, Odin, AS/2/067/88, Leanda, Dula, Valiant	1,2,3,4
IGER, Dyfed	Melys	1,2,3
SCOTLAND		
Aberdeen	Dula	1,2,3

Table 3. Virulence combination (race) frequencies identified from samples received in 1992 compared with previous years' races since 1982

Virulence Group	Race	Frequency (% total) 1982	1984	1986	1988	1990	1991	1992	No of isolates in 1992
OMV 1	2	0	0	0	0	0	0	0	0
1,2	3	39	32	31	32	0	3	0	0
1,3	4	4	2	0	0	0	0	0	0
1,2,3	5	43	64	63	68	66	19	83	35
1,2,4	6	0	0	0	0	7	5	0	0
1,2,3,4	7	14	2	6	0	27	73	17	7
No. of isolates tested		28	41	16	34	15	37	42	

CROWN RUST OF OATS

E.R.L. Jones and B.C. Clifford

AFRC Institute of Grassland and Environmental Research, Welsh Plant Breeding Station, Aberystwyth, Dyfed SY23 3EB, U.K.

Only one sample of oat crown rust was received in 1992 from Scotland. An isolate of *Puccinia coronata* was cultured from the infected leaves sampled from the winter oat cv. Image. Seedling tests on the 10 differential cultivars identified the isolate as being race 251. This virulence combination occurs commonly in the UK and is compatible with the differential cvs Appler, Bond and Saia.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1993

Variety diversificastion schemes to reduce the spread of mildew in spring barley and yellow rust in winter wheat have been produced by the UKCPVS Committee since 1975. In 1986, the barley scheme was expanded to include both winter and spring varieties. In 1988, spring wheat varieties were added to the wheat scheme. The schemes for mildew of barley and yellow rust of wheat which follow update those in the last Annual Report.

A scheme for brown rust of wheat was introduced in 1992. In the 1993 version, a number of varieties have remained unclassified, pending the results of additional tests with new isolates.

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 increasisng complexity of the mildew population. However, the situation will be under constant review and the mildew scheme will be reinstated when appropriate. Wheat varieties with good resistance to mildew are available and should be grown whenever possible.

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 possessissng different specific resistances because spores generated on one variety are largely non-virulent on the other.

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

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September 1992

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST IN WHEAT 1993

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

Choosing varieties to grow together

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

DG1	DG2	DG3	DG7	DG0
Brigadier	Admiral	Riband	Hereward	Genesis
Cadenza	Apollo		Spark	Alexandria(S)
Estica	Beaver		Talon	Canon(S)
Hunter	Haven	DG4		Rascal(S)
Hussar	Hornet			
Mercia	Slejpner	Avalon		
Pastiche		Galahad	DG8	
Torfrida				
Zodiac			Norman	
Concerto(S)		DG6	Axona(S)	
Promessa(S)			Baldus(S)	
Tonic(S)		Brock		

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

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

October 1992

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF BROWN RUST IN WHEAT 1993

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	DG2	DG0	DGU≠
Brigadier	Admiral	Brock	Cadenza
Estica	Apollo	Galahad	Hussar
Genesis	Beaver	Mercia	Pastiche
Hereward	Haven	Norman	Slejpner
Hunter	Hornet	Riband	Spark
Torfrida		Talon	Zodiac
Axona (S)		Alexandria (S)	Canon (S)
Baldus (S)	DG3	Tonic (S)	Rascal (S)
Concerto (S)			
Promessa (S)	Avalon		

≠ Unclassified resistances. Virulence detected in preliminary tests.

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

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

Revised September 1992

VARIETAL DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY 1993

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 0	
Bronze	(W)
Chestnut	(W)
Clarine	(W)
Frolic	(W)
Gaulois	(W)
Gypsy	(W)
Halcyon	(W)
Igri	(W)
Intro	(W)
Karisma	(W)
Marinka	(W)
Magie	(W)
Melusine	(W)
Panda	(W)
Pastoral	(W)
Plaisant	(W)
Posaune	(W)
Puffin	(W)
Sprite	(W)
Swift	(W)
Target	(W)
G.Promise	(S)
Triumph	(S)

DG 1	
Fighter	(W)
Firefly	(W)
Willow	(W)
Alexis	(S)
Atem	(S)
Chariot	(S)
Dandy	(S)
Derkado	(S)
Felicie	(S)
Forester	(S)
Goldie	(S)
Hart	(S)
Shirley	(S)

DG 3	
Golf	(S)
Klaxon	(S)

DG 4	
Pipkin	(W)
Dallas	(S)
Delita	(S)
Nugget	(S)
Sherpa	(S)
Tyne	(S)
Vodka	(S)

DG 7	
Chad	(S)
Decor	(S)
Dove	(S)
Platoon	(S)
Vintage	(S)

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

DG 10	
Kira	(W)
Torrent	(W)

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

DG 12	
Camarque	(S)
Omega	(S)

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

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

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