UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

Chairman: Dr R Johnson

Secretary: Dr R A Bayles
National Institute of Agricultural Botany
Huntingdon Road
Cambridge CB3 0LE, UK
(Tel: 01223 276381)

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THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

OBJECTIVES

The principal objective 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 of Grassland and Environmental Research, Aberystwyth - for brown rust of wheat and barley, Rhynchosporium and net blotch of barley, and mildew and crown rust of oats.

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.

The rationale and uses of the Survey have been described by Bayles, Clarkson & Slater (1997).

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 assign wheat and barley cultivars to diversification groups on the basis of their specific resistances. The results of the virulence tests and the diversification schemes are published in the Annual Report.

The information provided by the Survey is used in several ways. Isolates possessing new virulences are used by the National Institute of Agricultural Botany to evaluate the resistance of cereal cultivars in official trials and by plant breeders to select lines with effective forms of resistance. Isolates are also supplied to Universities and Colleges for research projects and teaching purposes. Versions of the cultivar diversification schemes, modified to meet regional requirements, are published by the National Institute of Agricultural Botany and by SAC in Scotland.

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

REFERENCES

Bayles, R. A., Clarkson, J. D. S. & Slater, S. E. (1997). The UK Cereal Pathogen Virulence Survey. In *The gene-for-gene relationship in plant-parasite interactions*, ed Crute, Holub & Burdon, pp 103-117, pub CABI, Oxon.

EXPLANATION OF TERMS USED TO DESCRIBE RESISTANCE AND VIRULENCE

SPECIFIC RESISTANCE AND SPECIFIC VIRULENCE

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

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

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

Specific resistances and virulences relating to particular cereal diseases are described by additional prefixes for crop (W = wheat, B = barley, O = oats) and disease (M = mildew, Y = yellow rust, B = brown rust, C = crown rust, R = *Rhynchosporium*, N = net blotch): 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.

- **Winter Cereal Disease Surveys, 1998**

A total of **445** randomly selected fields of **winter barley** and **436** fields of **winter wheat** were sampled as part of the 1998 national survey of cereal diseases. **1998 was the worst disease year for many years, particularly the wet weather diseases, such as leaf blotch, net blotch and *Septoria tritici***. Of the **barley** diseases, **leaf blotch** was the most severe disease at 4.7%, the highest level since 1983. **Brown rust** severity at 3.4% area of leaf 2 was the highest since the 1990 survey. **Net blotch** affected 3.2% area of leaf 2. **Mildew** was recorded less frequently than in 1997 and affected 0.8% of leaf 2 compared with 0.5% recorded in the previous survey. **Yellow rust** was not found this year. Of the **winter wheat** diseases, ***S. tritici*** was the most severe foliar disease for the eighth consecutive year, affecting 7.7% of the area of leaf 2, the highest level recorded since 1985. This level compared with 3.1% in 1997 and 2.1% in 1996. *S. tritici* was also present at trace levels on the ears. ***S. nodorum*** was present at 0.1% of the area affected of the second leaf and ears but only at trace levels on leaf 1. **Brown rust** affected 0.3% of the area of leaf 2 and was the highest level recorded since 1993. **Mildew** affected 0.1% of the area of leaf 2 and was the lowest level since the survey began in 1970. **Yellow rust** was recorded at 0.1% of the area affected on both leaf 1 and leaf 2 and at trace levels on the ears, the highest levels since 1990. The regional incidence and effect of cultivar on disease levels are also reported in the paper and the implications discussed.

- **Mildew of Wheat**

Fewer samples were received in 1998, due to unfavourable infection conditions. Virulence frequencies of ***V2*, *4b*, *5*, *6*, *8* and *Ta2*** were very high, corresponding to large acreages of cultivars carrying *Pm2*, *4b*, *6* and *8*. Thus, the pathotype *V2,4b,5,6,8,Ta2* predominated, representing 38% of the pathotypes recorded. Most winter wheat cultivars, including newcomers **Buchan**, **Claire** and **Malacca**, could be infected by the majority of isolates, although some have good **partial** resistance. **Shamrock** and **Soissons** have good mildew resistance, seemingly conferred by unidentified specific resistance factors.

- **Yellow Rust of Wheat**

Yellow rust was widespread in 1998 and some 99% of isolates tested possessed virulence for **WYR17**. One new pathotype, **WYV1,2,3,4,6,9,17**, was identified. Adult plant tests confirmed the susceptibility of a large number of current cultivars to isolates possessing **WYV17** and **WYV6,17**. However, the continued effectiveness of the resistance of a number of other cultivars was also highlighted.

- **Brown Rust of Wheat**

There was a higher incidence of this disease in 1998. The number of isolates carrying virulence to two or fewer of the standard seedling differentials has increased in frequency since the early part of the decade. This is mainly due to the decline in the frequency of isolates carrying **WBV-1**. Adult plant tests in the field and in controlled environments identified high levels of resistance in several of the current wheat cultivars.

- **Mildew of Barley**

There has been **little change** in the barley mildew populations in the UK in recent years. The majority of winter cultivars on the NIAB Recommended List are potentially at risk of infection by a large proportion of the mildew population. The spring barley Riviera, a ***mlo*** variety, showed noticeable levels of mildew in 1998, although the overall virulence frequency was low. However, pustule transfer experiments in Northern Ireland suggested a shift, albeit small, in **virulence for *mlo***.

- **Yellow Rust of Barley**

Despite some early reports of infection in crops, **no yellow rust** was confirmed on samples received at NIAB. It should be noted that there is still a potential for an epidemic in **winter barley**, as the very susceptible cultivars Regina and Melanie are expected to account for *c* 25% of the UK winter barley acreage this season.

- **Brown Rust of Barley**

Of the seedling differential cultivars, only Cebada Capa (**BBR-7**) carried resistance effective against all the virulences carried by the 1998 isolates. A number of winter barleys expressed resistance to specific isolates of brown rust. Some of the currently recommended spring barleys were resistant as adult plants to one or more of the test isolates. A few spring cultivars carried overall resistance to one of the isolates.

- ***Rhynchosporium* of Barley**

The frequency of 1998 isolates carrying virulences **BRV-6** and **BRV-8** remained at a low level. BRV-6, previously found only in combination with BRV-5, was identified in one isolate lacking virulence to the differential cultivar La Mesita (BRR-5). Adult plant glasshouse tests identified increased virulence to the winter barley **Manitou**. The responses of cv **Angela** to the isolates suggests it carries resistance **BRR-5**. The spring barleys were all susceptible but expressed a range of quantitative responses to the isolates.

- **Net Blotch of Barley**

A high proportion of the 1998 samples were received from winter barley cv **Regina** which has a NIAB disease rating of 8 and which has previously shown good levels of resistance in adult plant glasshouse tests. It was susceptible in similar tests to a mixture of isolates cultured from the 1998 leaf samples. Some of the spring and winter barleys currently on the NIAB Recommended List were classified as resistant to the isolates.

- **Soil-borne Mosaic Viruses of Barley**

Only **39** infected samples were received in 1998: **12** contained barley mild mosaic virus (BaMMV) alone, **21** barley yellow mosaic virus (BaYMV) alone and **6** had both viruses. This is the smallest number of samples since the survey began in 1987 and provided insufficient data to analyse cultivar responses. No new outbreaks of resistance-breaking BaYMV were reported.

- **Mildew of Oats**

Two races were identified from the 1998 samples: **race 5** was found in **25** of the isolates and **race** 7, which carries virulence to all the seedling differential cultivars but which has remained at a low frequency since it was identified in 1980, was found in **2** isolates. A number of winter and spring oat cultivars expressed a range of quantitative susceptible responses to two races of the pathogen in glasshouse tests.

- **Crown Rust of Oats**

Seedling tests with the 1998 isolates identified the commonly occurring races: **251** and **275**. The spring oat cv Sailor, and the winter oat cv Millennium, expressed overall resistance to two isolates of rust under glasshouse conditions.

WINTER CEREAL DISEASE SURVEYS, 1998

N.V. HARDWICK, J.E. SLOUGH and D.R. JONES[1]

Central Science Laboratory, Sand Hutton, York YO41 1LZ
[1] ADAS Rosemaund, Preston Wynne, Hereford HR1 3PG

A total of 445 randomly selected fields of winter barley and 436 fields of winter wheat were sampled as part of the 1998 national survey of cereal diseases. 1998 was the worst disease year for many years, particularly the wet weather diseases such as leaf blotch, net blotch and *Septoria tritici*. Of the barley diseases, leaf blotch was the most severe disease at 4.7%, the highest level since 1983. Brown rust severity at 3.4% area of leaf 2 was the highest since the 1990 survey. Net blotch affected 3.2% area of leaf 2. Mildew was recorded less frequently than in 1997 and affected 0.8% of leaf 2 compared with 0.5% recorded in the previous survey. Yellow rust was not found this year. Of the winter wheat diseases, *S. tritici* was the most severe foliar disease for the eighth consecutive year, affecting 7.7% of the area of leaf 2, the highest level recorded since 1985. This level compared with 3.1% in 1997 and 2.1% in 1996. *S. tritici* was also present at trace levels on the ears. *S. nodorum* was present at 0.1% of the area affected of the second leaf and ears but only at trace levels on leaf 1. Brown rust affected 0.3% of the area of leaf 2 and was the highest level recorded since 1993. Mildew affected 0.1% of the area of leaf 2 and was the lowest level since the survey began in 1970. Yellow rust was recorded at 0.1% of the area affected on both leaf 1 and leaf 2 and at trace levels on the ears, the highest levels since 1990. The regional incidence and effect of cultivar on disease levels are also reported and the implications discussed.

INTRODUCTION

Plant pathologists at the Central Science Laboratory (CSL) and ADAS have conducted annual disease surveys of winter barley crops since 1981, with the exception of 1984 and 1985, and winter wheat since 1970, apart from 1983 and 1985 (Hardwick *et al.*, 1998a, 1998b; Polley & Thomas, 1989; Polley *et al.*, 1993).

This summary report contains the results of the survey of foliar and stem base diseases of winter barley and winter wheat for the 1997-98 growing season, and includes information on fungicide use. The results are compared, where appropriate, with those from previous surveys.

METHODS

The 1998 survey of leaf and stem-base diseases of winter barley was carried out in June and early July when crops were at the watery-ripe to early-milk growth stage (GS 71-73). The winter wheat survey was carried out in July when crops were at the early- to medium-milk growth stage (GS 73-75).

This year the regions have been changed from the old ADAS Regions to those of Government Office Regions (Table 1). The decision was taken because ADAS Regions have changed on a number of occasions since the survey began and are no longer relevant. It was considered that the move to the use of Government Office Regions would give some stability to the survey for the foreseeable future.

Table 1 Key to regions

Code	Region	County
NE	North East	Cleveland & Darlington, Durham, Northumberland, Tyne & Wear,
NW	North West and Merseyside	Cheshire, Cumbria, Greater Manchester, Lancashire, Merseyside
Y&H	Yorkshire & the Humber	East Riding & Northern Lincolnshire, North Yorkshire, South Yorkshire, West Yorkshire
EM	East Midlands	Derbyshire, Leicestershire, Lincolnshire, Northamptonshire, Nottinghamshire, Rutland
WM	West Midlands	Hereford & Worcester, Shropshire, Staffordshire, Warwickshire, West Midlands
EAST	Eastern	Cambridgeshire, Bedfordshire, Essex, Hertfordshire, Norfolk, Suffolk
SE	South-East and Greater London	Berkshire, Buckinghamshire, Greater London, Hampshire, Kent, Oxfordshire, Surrey, East Sussex, West Sussex
SW	South-West	Cornwall, Devon, Dorset, Gloucestershire, North Somerset & South Gloucestershire, Somerset, Wiltshire
WALES	Wales	All Welsh Counties

The farm addresses were selected at random from the returns of the June 1997 MAFF agricultural census. The distribution of farms between regions was proportional to the regional area of winter barley and wheat grown, except for Wales where additional addresses were requested in order to obtain sufficient sites for data comparison, and on the size of the arable area of the farms to be surveyed. A total of 445 randomly selected fields of winter barley and 436 fields of winter wheat were sampled. Calculation of the national results, based on a full stratification according to location and farm size resulted in the utilisation of data from 356 and 380 samples of winter wheat and winter barley respectively. A questionnaire giving agronomic details such as cultivar, sowing date and previous cropping, as well as details of all pesticide applications, was completed for each sample.

RESULTS

Winter barley

Severity of foliar and stem disease

Three diseases, net blotch, leaf blotch and brown rust reached levels of more than 3.0% area leaf 2 affected (Table 2). Leaf blotch was the most severe disease at 4.7%, the highest level since 1983 (Fig 1). Brown rust severity at 3.4% area of leaf 2 was the highest since the 1990 survey. Net blotch affected 3.2% area of leaf 2. Mildew was recorded less frequently than in 1997 and affected 0.8% of leaf 2 compared with 0.5% recorded in the previous survey (Fig. 1). Yellow rust was not found in this survey and has only been recorded at trace levels in the previous two surveys.

Table 2 National foliar disease levels (per cent leaf area affected)

	Leaf 1	Leaf 2
Mildew	0.3	0.8
Brown rust	2.4	3.4
Net blotch	2.1	3.2
Leaf blotch	1.2	4.7
Leaf spot	tr	tr
Halo spot	tr	tr
Yellow rust	0.0	0.0
Insect damage	0.4	0.3
Green leaf area	79.6	60.5

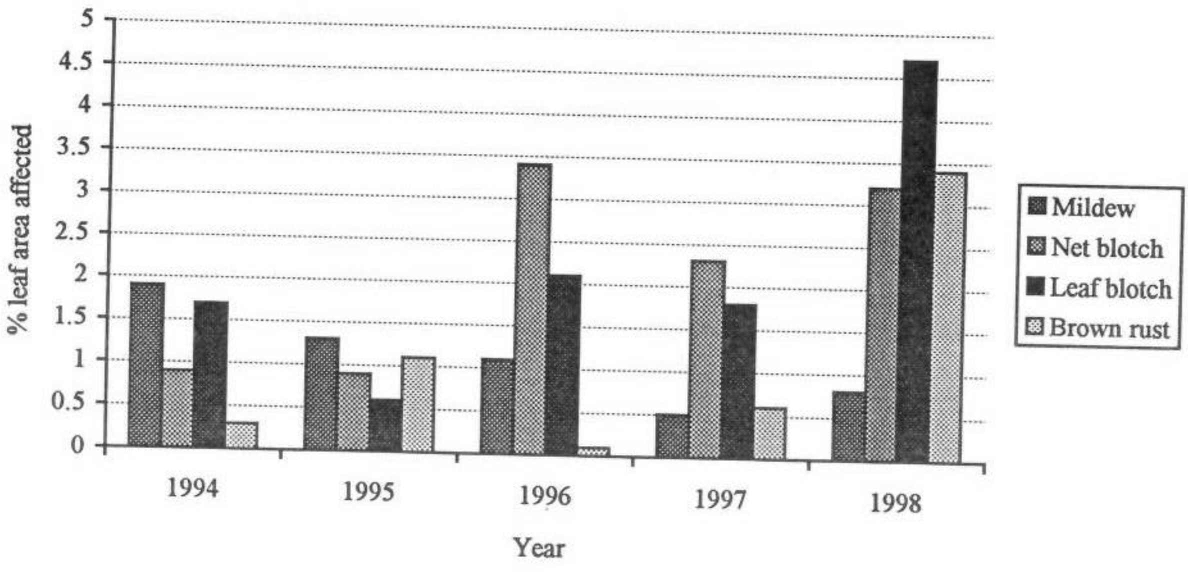

Fig. 1 National foliar disease levels (mean % area leaf 2 affected)

Eyespot was recorded in 84% of crops, slightly less than in 1997, and was not as severe, with 7.2% of stems affected by moderate and severe symptoms compared to 9.1% in 1997 and 6.6% in 1996. Sharp eyespot was recorded more frequently than in 1997, affecting 36% of crops sampled with moderate and severe symptoms affecting 1.9% of stems. Fusarium symptoms were present in 91% of crops, with nodal fusarium found at moderate levels on 9.8% of stems (Table 3).

Regional disease severity

Levels of mildew were low but higher than in 1997. Net blotch was most severe in the North East (5.3% area leaf 2) and the Midlands (4.9% area leaf 2 in the east and 4.3% in the west). Leaf blotch was most severe in the South West and Wales and brown rust in the Yorkshire and Humber Region (6.7% area leaf 2) (Table 4; Fig. 2).

Table 3 National stem base disease levels (per cent stems affected)

	Slight	Moderate	Severe
Eyespot	16.8	7.1	0.1
Sharp eyespot	2.2	1.7	0.2
Nodal fusarium	12.6	9.8	tr
Internodal fusarium	4.5	1.0	tr
All fusarium	15.4	10.5	tr

Table 4 Regional foliar disease levels (per cent area leaf 2 affected)

Region	No. of samples	Mildew	Brown rust	Net blotch	Leaf botch	Leaf spot	Halo spot	Yellow rust
NE	21	0.9	3.6	5.3	1.7	tr	0.0	0.0
NW	15	0.5	0.9	1.3	9.1	0.0	0.0	0.0
Y & H	67	0.9	6.7	1.5	1.6	tr	0.0	0.0
EM	63	0.7	4.1	4.9	1.7	tr	0.0	0.0
WM	46	1.5	2.6	4.3	6.0	tr	0.0	0.0
EAST	94	0.7	2.4	3.4	0.7	tr	tr	0.0
SE	49	0.9	2.0	2.6	6.5	tr	tr	0.0
SW	61	0.5	4.7	2.8	13.9	tr	0.0	0.0
WALES	29	0.7	2.8	3.2	11.7	tr	0.0	0.0
National (stratified)	380	0.8	3.4	3.2	4.7	tr	tr	0.0

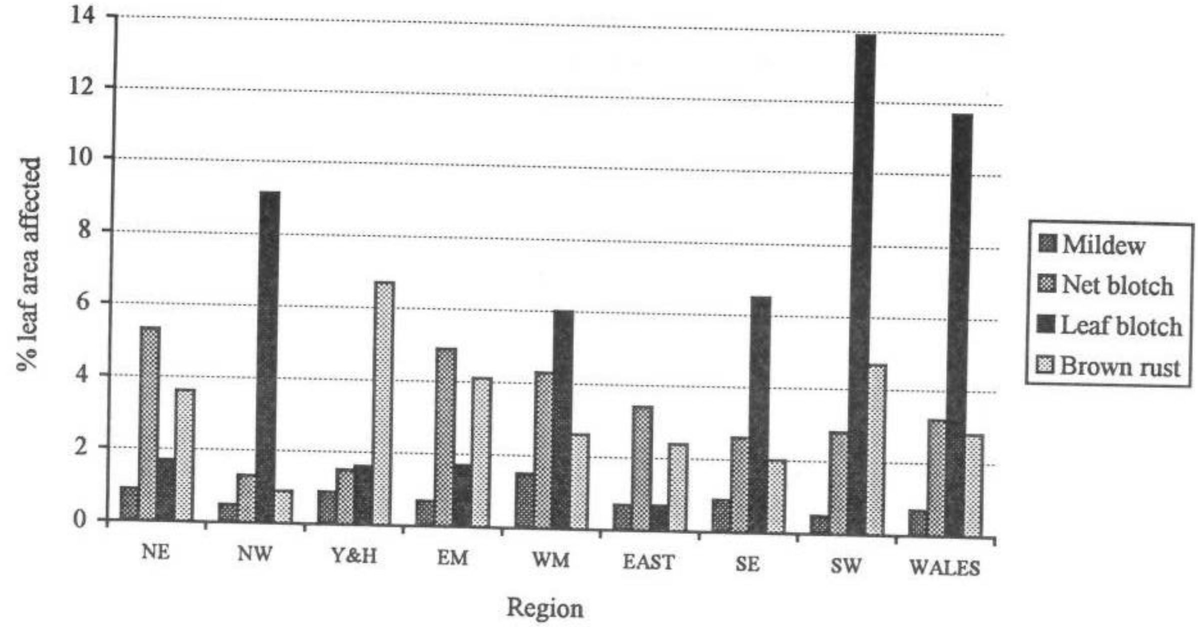

Fig. 2 Regional foliar diseases levels (mean % area leaf 2)

The effect of cultivar on disease severity

Regina, Intro, and Fighter were the most popular cultivars grown, accounting for 22%, 15% and 13% of crops, respectively. From the ten most popular cultivars in the stratified sample the highest levels of leaf blotch and mildew were recorded on Intro at 7.9% and 1.7% of the area of leaf 2 respectively (NIAB ratings 5 and 6 respectively). Brown rust was most severe on Hanna affecting 12.7% area of leaf 2, NIAB rating 7. The highest net blotch levels were found on Muscat with 14.8% area of leaf 2 affected (NIAB rating 7) (Fig. 3).

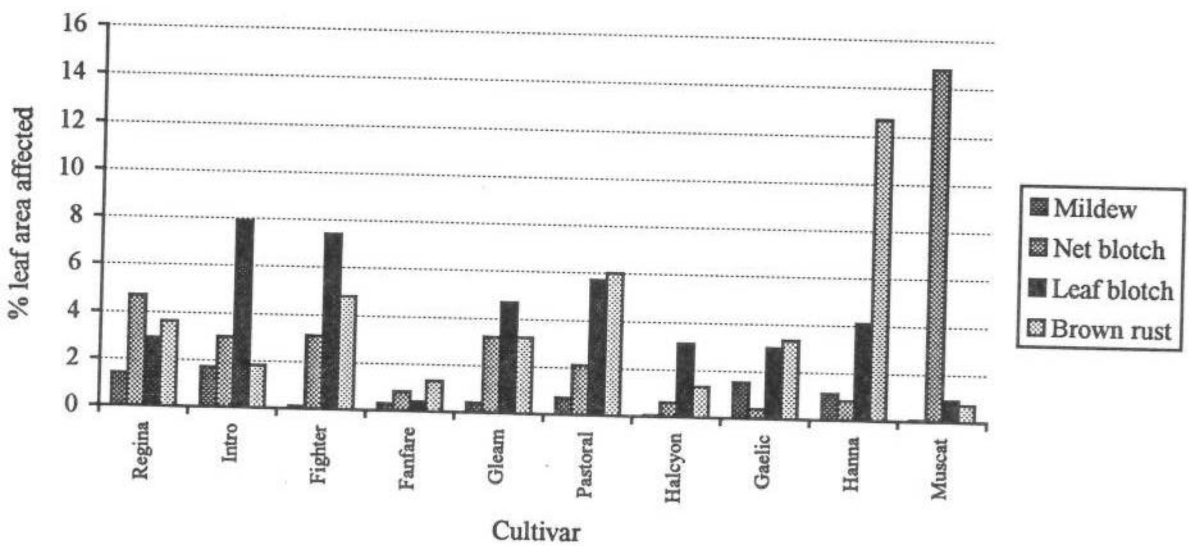

Fig. 3 Foliar diseases on main cultivars (mean % area leaf 2)

Leaf blotch and sharp eyespot appear to be more severe on crops drilled before 24 September, whilst eyespot was more severe when drilled between 24 and 30 September and more damaging in crops following a cereal.

Fungicide sprays were used on 94% of crops. Eight per cent of crops were treated with a fungicide before the end of tillering, 73% at or around GS 31 and 62% at or after flag leaf emergence. Forty one per cent of crops received a single spray, 62% at *c.* GS 31. Forty two per cent were sprayed twice, with the majority (77%) at GS 31 with a second spray at or after GS 37. Eleven per cent of crops received three or more fungicide sprays, an increase of 4% when compared to the 1997 survey. The most commonly applied fungicide products were Opus (83 applications), Unix (56 applications), Punch C (55 applications) and Sanction (50 applications). The number of different foliar applied fungicide products totalled 97 with 23 active ingredients. Seventy nine per cent of crops in the survey were grown from certified seed, and 95% of all crops were grown from fungicide treated seed.

Winter wheat

Severity of foliar and stem disease

Nationally the amount of foliar disease was higher than in any year since 1985, with levels more than twice those recorded in 1997. For the eighth consecutive year *Septoria tritici* (teleomorph: *Mycosphaerella graminicola*) was the most severe foliar disease, affecting 7.7% of the area of leaf 2, the highest level recorded since 1985. This level compared with 3.1% in 1997 and 2.1% in 1996. *S. tritici* was also present at trace levels on the ears (Table 5). *Septoria nodorum* (teleomorph: *Stagonospora nodorum*) was present at 0.1% of the area affected of the second leaf and ears but only at trace levels on leaf 1. Brown rust affected 0.3% of the area of leaf 2 and were the highest recorded since 1993 (Fig. 4). Mildew affected 0.1% of the area of leaf 2 and were the lowest since the survey began in 1970. Yellow rust was recorded at 0.1% of the area affected on both leaf 1 and leaf 2 and at trace levels on the ears, the highest levels since 1990. Fusarium ear blight symptoms were recorded in 61% of samples, higher than in any survey since records began in 1987, with a mean of 12% of ears affected; and with glume spot at 15.4% of ears compared with 8.6% in the previous year.

Table 5 National foliar disease levels (per cent area affected)

	Leaf 1	Leaf 2	Ear
Mildew	tr	0.1	tr
S. tritici	2.8	7.7	tr
S. nodorum	tr	0.1	0.1
Yellow rust	0.1	0.1	tr
Brown rust	0.2	0.3	-
Didymella	0.0	0.0	-
Cephalosporium	0.0	0.0	-
Tan spot	0.0	0.0	-
Insect damage	0.8	1.0	-
Green leaf area	89.9	79.7	-

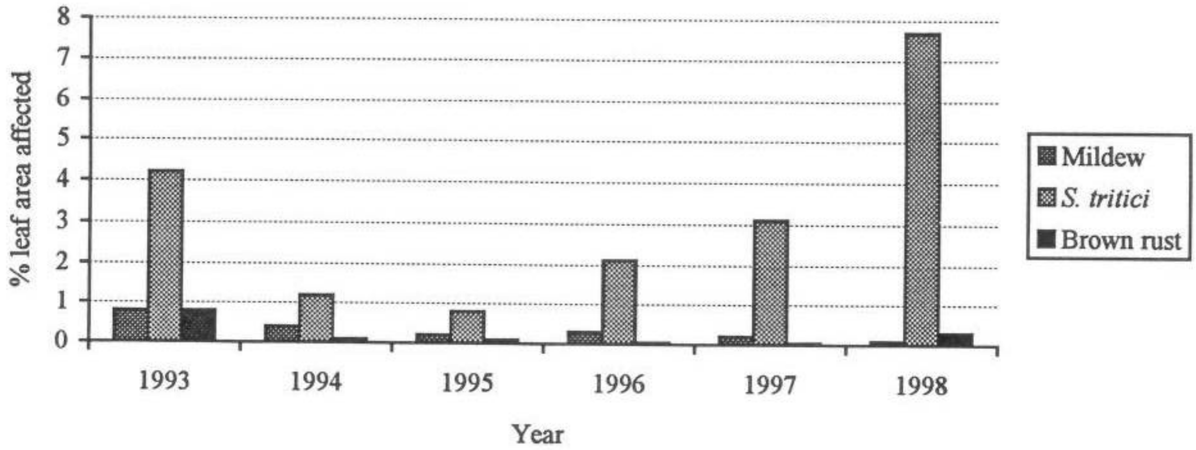

Fig. 4 National foliar disease levels (mean % area leaf 2 affected), 1993-1998

Levels of eyespot, at 18.5% stems affected with moderate and severe symptoms, were higher than in any survey since 1987 (18.7%) (Fig 5). Moderate and severe symptoms of sharp eyespot affected 4.6% of stems and were higher than those recorded in 1997 (4.2%) and in 1996 (2.5%) (Fig. 6). The fusarium complex affected 24% of stem bases which was lower than the 28.9% of 1997 and with more than a two-fold reduction in moderate symptoms.

Table 6 National stem base disease levels (per cent stems affected)

	Slight	Moderate	Severe
Eyespot	21.4	17.4	1.2
Sharp eyespot	5.1	4.3	0.3
Nodal fusarium	14.1	2.6	tr
Internodal fusarium	7.4	2.3	0.1
All fusarium	19.2	4.6	0.2

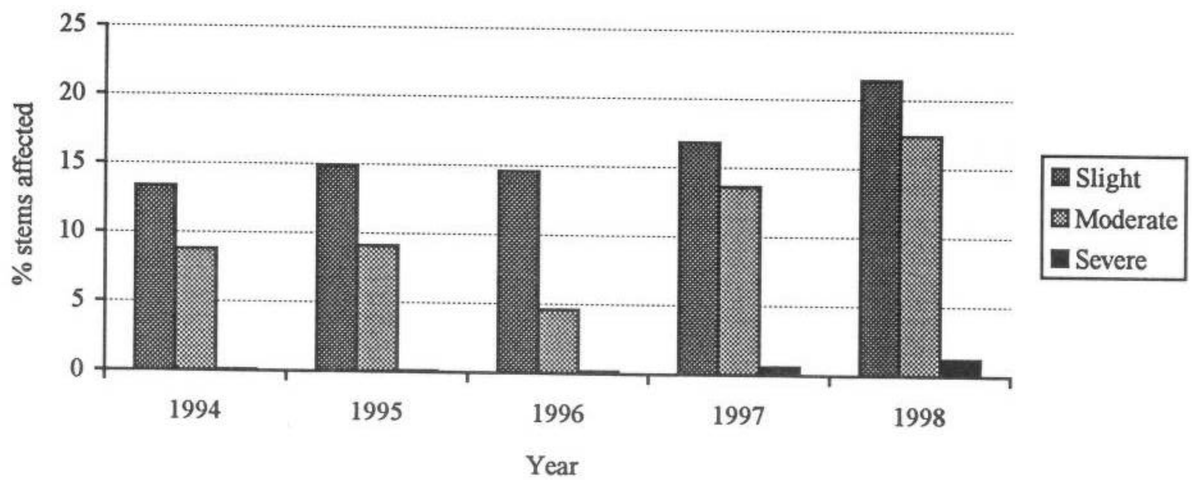

Fig. 5 National levels of eyespot (mean % stems affected)

Table 7 National fusarium levels on the ears

Year	% samples affected		% ears affected	
	Ear blight	Glume spot	Ear blight	Glume spot
1994	5.2	24.6	0.3	2.0
1995	2.0	11.3	0.1	0.7
1996	1.9	10.6	0.1	0.7
1997	21.8	62.7	1.6	7.0
1998	61.2	41.0	12.1	3.3

Take-all was present in 45% of crops. Take-all patches were recorded in 17.7% of crops compared with 2.8% in 1997 (sum of categories 2-4) (Table 8).

Table 8 National take-all levels

	Take-all category*					Total with take-all
	0	1	2	3	4	
Number of crops (1997)	287.0	55.0	4.0	2.0	4.0	65.0
Per cent of total (1997)	81.5	15.6	1.1	0.6	1.1	18.5
Number of crops (1998)	187.0	92.0	32.0	22.0	6.0	152.0
Per cent of total (1998)	55.2	27.1	9.4	6.5	1.8	44.8

* 0 = no take-all seen, 1 = a scatter of plants showing premature ripening, 2 = occasional small patches (less than 5m across) showing premature ripening and/or stunting - less than 1% of field affected, 3 = many small or few large areas affected - 1% to 10% of field affected and 4 = many large areas affected - more than 10% of field area affected

Sharp eyespot was present in 65% of crops. Moderate and severe levels were higher compared with the previous two years (Fig. 6).

Symptoms of BYDV were recorded in 21% of crops, three times more than in either of the previous two surveys. Patches of BYDV symptoms were similar when compared with 1996 and 1997 but a scattering of plants showing premature ripening affected 18.2% of samples, an increase from the 1997 survey (5.5%).

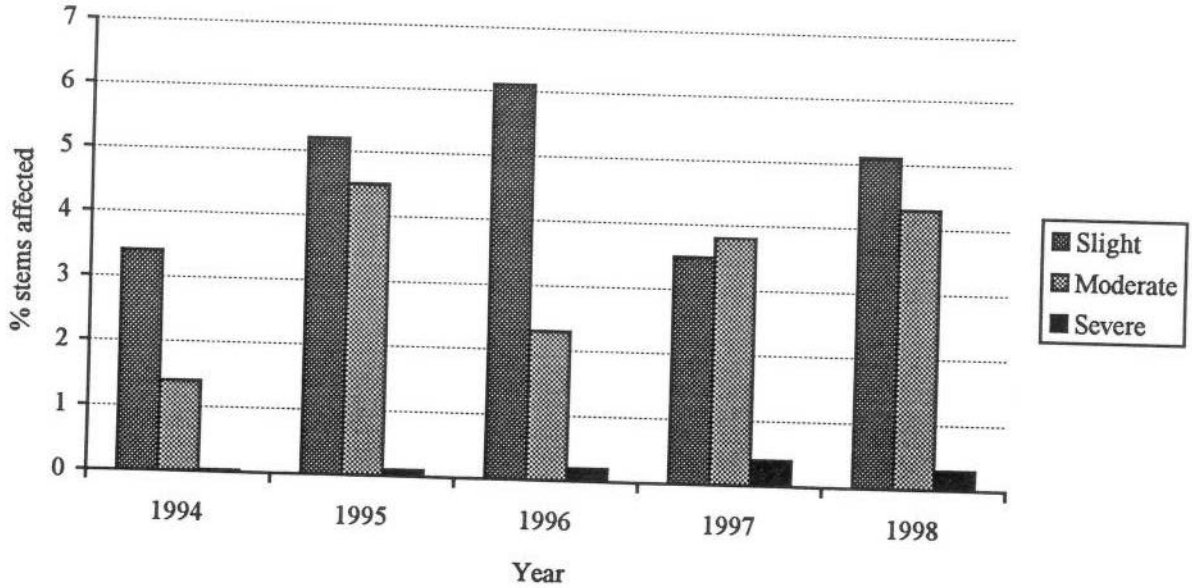

Fig. 6 National levels of sharp eyespot (mean % stems affected)

Regional disease incidence and severity

Past surveys have indicated that the areas most at risk from *S. tritici* are Wales and the South-West. In 1998, the highest levels occurred in the North East, North West, South West and Wales and the lowest levels in the South East. The highest levels of brown rust were also recorded in Wales. Mildew was recorded at less than 0.3% of leaf 2 in all regions (Fig. 4). Yellow rust was recorded at trace levels in all regions except the North West where it was not found and in the East Midlands and Wales at 0.3% and 0.4% area of leaf 2 respectively. *S. nodorum* was recorded at less than 0.3% of leaf 2 in all regions (Table 9).

Table 9 Regional foliar disease levels (% area leaf 2)

Region	No. of samples	Mildew	*Septoria tritici*	*Septoria nodorum*	Yellow rust	Brown rust	*Didy-mella*	Tan spot	*Cephalo-sporium*
NE	17	0.1	14.2	tr	tr	0.7	0.0	0.0	0.0
NW	7	0.1	28.4	0.2	0.0	tr	0.0	0.0	0.0
Y&H	59	0.1	8.9	tr	tr	0.4	0.0	0.0	0.0
EM	77	0.1	6.7	tr	0.3	0.2	0.0	0.0	0.0
WM	38	0.3	9.4	0.2	tr	0.3	0.0	0.0	0.0
EAST	106	0.1	4.8	0.1	tr	0.4	0.0	0.0	0.0
SE	56	0.1	3.6	tr	tr	0.3	0.0	0.0	0.0
SW	45	0.1	17.2	0.1	tr	0.3	0.0	0.0	0.0
WALES	31	0.1	13.4	tr	0.4	1.6	0.0	0.0	0.0
National (stratified)	356	0.1	7.7	0.1	0.1	0.3	0.0	0.0	0.0

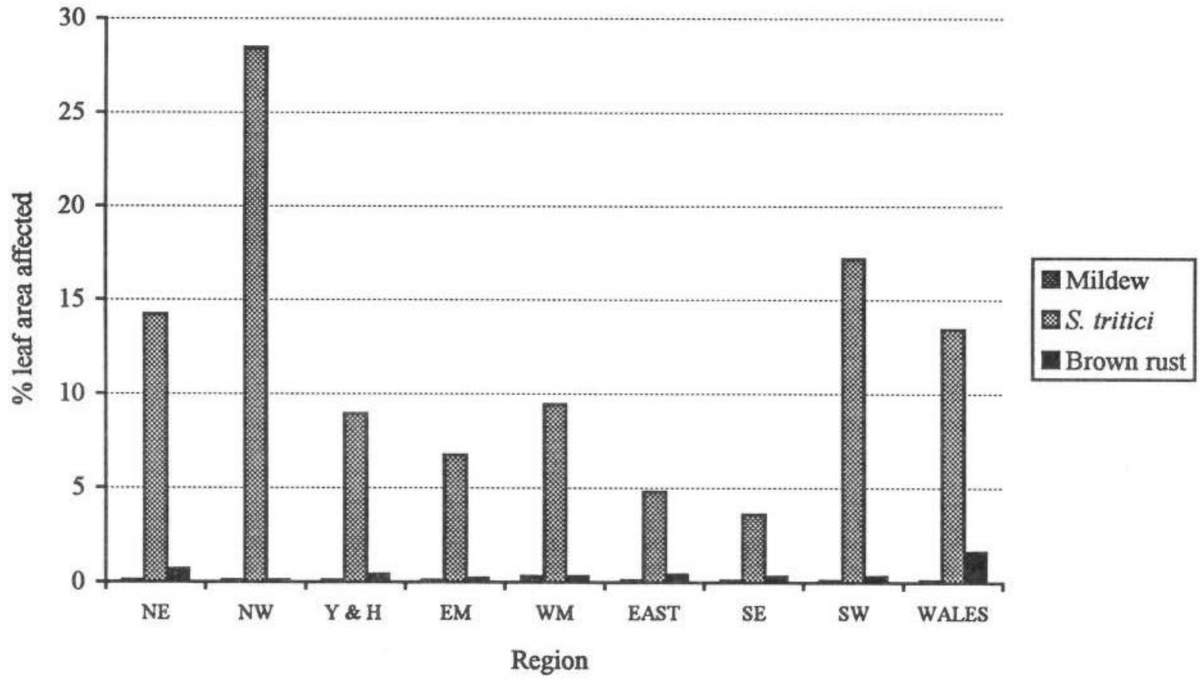

Fig. 7 Regional foliar diseases levels (mean % area leaf 2)

Moderate levels of eyespot were generally highest on samples from the North West (Fig. 8).

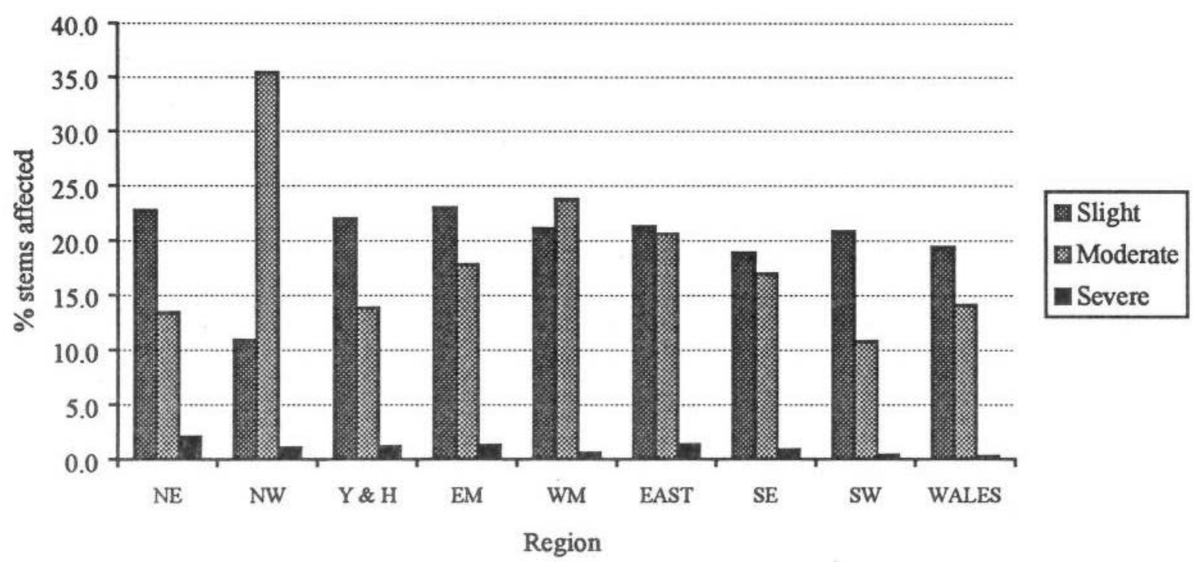

Fig. 8 Regional eyespot levels (mean % stems affected)

Moderate sharp eyespot levels were also most severe in the North West. The lowest levels were recorded in samples from the East (Fig. 9).

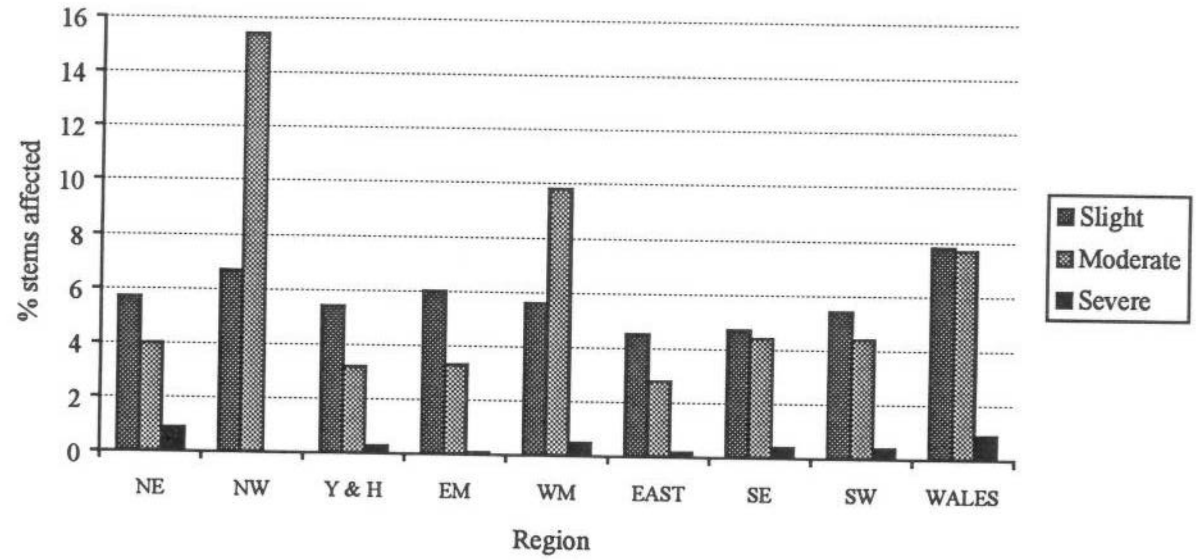

Fig. 9 Regional levels of sharp eyespot (mean % stems affected)

Effect of cultivar on disease severity

Riband, at 18% of crops, was the most commonly sampled cultivar in the survey; a position it has held for the eighth successive year. Consort was present in 14% of samples followed by Brigadier at 10%. Buster carried the highest levels of *S. tritici* (17.5% area of leaf 2), brown rust (1.9% area of leaf 2) and mildew (0.7% area of leaf 2) NIAB ratings 5, 3, and 5 respectively (Fig. 7). Brigadier had the highest levels of yellow rust (0.2% area leaf 2). The most common of the new cultivars being Equinox at 4% of the stratified survey (Fig. 10).

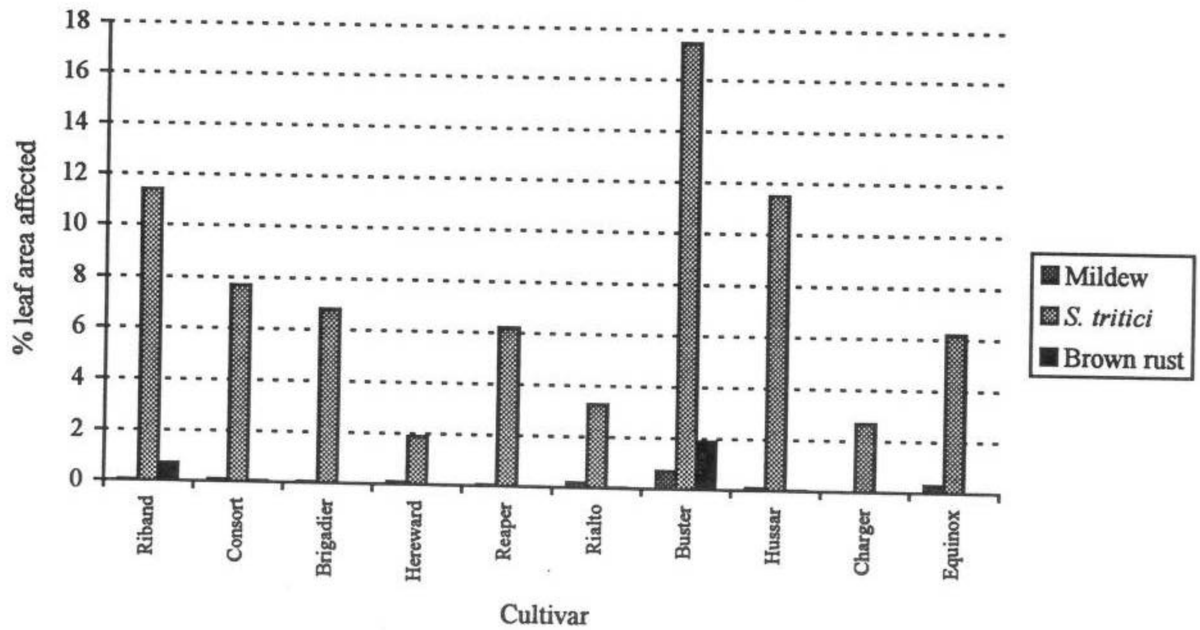

Fig. 10 Foliar diseases on main cultivars (mean % area leaf 2)

For the seventeenth successive survey the lowest levels of eyespot were found in crops following grass. In contrast sharp eyespot levels were most severe following grass but least severe following pulse/legume. Moderate and severe levels of fusarium stem base diseases were highest following another cereal. Take-all levels were lowest following pulse or grass but most severe following wheat. Monoculture had little effect on levels of either fusarium or sharp eyespot, but eyespot levels tended to be highest following a third or subsequent wheat and take-all most severe in a second wheat. A non-cereal break of two or more years reduced the levels of moderate and severe eyespot. Take-all symptoms were more prevalent in crops where no break had occurred. *S. tritici* and take-all were most severe in crops drilled in late October and eyespot and sharp eyespot in crops drilled at the beginning of October. Fusarium stem base disease was most severe in crops drilled after October.

Fungicide sprays were used on 98% of crops, with 89% receiving two or more treatments. The most popular regime, applied to 28% of crops, was a three-spray programme with the first spray applied at GS 31, a second spray at GS 39 followed by a third aimed at GS 59. Thirty seven per cent of crops received a two-spray programme. The most popular, applied to 21% of crops, was a first spray at GS 31, followed by a second at GS 39. Crops received on average 2.5 fungicide spray applications, an increase of 0.3% when compared to the previous three surveys. Seventy seven per cent of crops were grown from certified seed with 98% of crops sown with fungicide treated seed. Seventy three per cent of crops were treated with insecticides. A total of 366 insecticide products were applied 52% in the autumn, 20% from the spring to GS 37 and 27% from GS 38 to 75.

DISCUSSION

1998 was the worst year for disease for many years, particularly the wet weather diseases such as leaf blotch, net blotch and *S. tritici*. Despite much expenditure on research into the control of cereal diseases, particularly since 1985 when *S. tritici* became a major disease of winter wheat, the results this year have been poor. On average over 1.6 sprays were applied to winter barley and 2.5 sprays to winter wheat. Fungicide sprays were used on 94% of winter barley crops and 98% on winter wheat, with 89% of wheat crops receiving two or more treatments. The wet conditions of the spring and early summer of 1998 meant that it was difficult to spray crops at the appropriate time and when it was possible to do so disease levels were already high. The importance of sowing disease resistant cultivars as a first line of defence is amply demonstrated by the results of the 1998 survey.

ACKNOWLEDGEMENT

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REFERENCES

Hardwick, N.V., Jones, D.R. & Slough J.E. (1998a). CSL/ADAS winter wheat and winter barley disease surveys, 1997. *United Kingdom Cereal Pathogen Virulence Survey 1997 Annual Report*, pp 6-15.

Hardwick, N.V., Jones, D.R. & Slough J.E. (1998b). Surveys of cereal diseases in England and Wales, 1988-97. Proceedings *7th International Congress of Plant Pathology, 1998*. Edinburgh UK: ISPP, 4.9.2.

Polley, R.W. & Thomas, M.R. (1989). Surveys of diseases of winter wheat in England and Wales, 1976-1988. *Annals of Applied Biology* **119**, 1-20.

Polley, R.W., Thomas, M.R., Slough, J.E. & Bradshaw, N.J. (1993). Surveys of diseases of winter barley in England and Wales, 1981-1991. *Annals of Applied Biology* **123**, 287-307.

MILDEW OF WHEAT

J.D.S. CLARKSON and S.E. SLATER

National Institute of Agricultural Botany, Cambridge

Fewer samples were received in 1998, due to unfavourable infection conditions. Virulence frequencies of *V2*, *4b*, *5*, *6*, *8* and *Ta2* were very high, corresponding to large acreages of cultivars carrying *Pm2*, *4b*, *6* and *8*. Frequencies of *Vd*, *Br* and *Ax* declined, due to lower numbers of Cadenza isolates tested. The total number of pathotypes recorded continues to decline. Again, the pathotype *V2,4b,5,6,8,Ta2* predominated, representing 38% of the pathotypes recorded. Most cultivars, including newcomers Buchan, Claire and Malacca, could be infected by the majority of isolates, although many have good partial resistance. Shamrock and Soissons have unidentified specific resistance factors; that of Soissons has been designated *MlSs*.

INTRODUCTION

Powdery mildew (*Blumeria* [syn *Erysiphe*] *graminis* f sp *tritici*) levels in winter wheat crops were normal throughout the autumn, winter and early spring but subsequently declined dramatically, due to wet weather from April onwards. During the summer months, infection was generally confined to lower leaves and stems, even in susceptible cultivars. Spring wheat crops also contained little mildew. Consequently, the number of samples received was the lowest so far this decade.

METHODS

A total of 186 samples of wheat mildew was received in 1998, mostly from trial plots. 74 samples failed to produce viable conidia but single colony isolates from the remaining 112 samples were cultured and subsequently tested. The isolates were taken from infected leaves of the following cultivars:

Winter cultivars	No. of isolates		No. of isolates		No. of isolates
Buster	9	Reaper	7	Blaze	5
Claire	9	Soissons	7	Cadenza	5
Rialto	9	Brigadier	6	Charger	5
Shango	9	Cantata	6	Malacca	5
Chaucer	8	Caxton	6	Aardvark	4
Consort	8	Hussar	6	Abbot	4
Equinox	8	Madrigal	6	Buchan	4
Hereward	8	Riband	6	Harrier	4
Maverick	8	Savannah	6	Shamrock	3
Spark	8				

Estica, Fresco, Galahad and Ritmo: 1 each
Two isolates were also taken from each of the spring cultivars Axona and Chablis.

The samples were collected from the following locations:

	No. of isolates		No. of isolates
Wye, Kent	52	Headley Hall, N Yorks.	9
NIAB, Cambridge	45	Cockle Park, Northumb.	8
Bridgets, Hants.	41	Morley, Norfolk	4
Long Sutton, Lincs.	28		
Total	**187**		

Isolates were inoculated onto detached leaf segments of differential cultivars using a settling tower and assessed using the method of Moseman *et al*, 1965. The differential cultivars used to test the isolates for virulence factors are shown in Table 1.

Table 1 Differential cultivars used to determine virulence factors in isolates of wheat mildew in 1998.

Differential cultivar	European code	Resistance genes
Cerco	none	None
Galahad	Pm2	*Pm2*
Chul	Pm3b	*Pm3b*
Armada	Pm4b	*Pm4b*
Flanders	Pm5	*Pm5*
Brimstone	Pm2, Pm6	*Pm2, Pm6*
Clement	Pm8	*Pm8*
Amigo	Pm17	*Pm17*
Maris Dove	Mld	*Mld*
Brock	Pm2, MlTa2	*Pm2,* Unknown
Mercia	Pm5, MlTa2	*Pm5,* Unknown
Tonic	MlTo	Unknown
Broom	MlBr	*Pm3d* ?
Sicco	Pm5, MlSi2	*Pm5,* Unknown
Wembley	MlSo Pm12?	Unknown
Axona	MlAx	Unknown
Soissons	MlSs*	Unknown

* tentative designation for specific resistance factor

RESULTS

Virulence frequencies

Virulence for *Pm2* was again found in all the samples tested. The levels of *V4b* and *V6* continued to increase and are also now at the maximum frequency. This is due to selection by the majority of the winter wheat area, as 50% of wheat cultivars carry *Pm2*, 60% carry *Pm4b* and 87% carry *Pm6*. The virulence frequency for *V8* also remains high; the area of wheat with *Pm8* has increased from 11% in 1997 to 41% in 1998.

Table 2 Frequency of wheat mildew virulence factors in isolates from infected leaves collected in 1992 - 1998, and 1998 areas of cultivars with the corresponding resistance.

	Frequency of virulence factors (%)							Area
Virulence factor	1992	1993	1994	1995	1996	1997	1998	1998*
2	99	98	99	99	100	100	100	50
3b	-	-	-	4	3	4	1	0
4b	73	79	84	88	93	98	100	60
5	90	95	92	92	93	95	88	<1
6	76	78	80	89	96	99	100	87
8	86	93	93	95	96	98	97	41
17	-	-	-	10	15	16	8	0
d	27	15	20	19	33	26	18	<1
2,Ta2	60	80	82	85	92	93	86	<1
To	24	18	24	18	29	29	16	<1
Br	31	20	27	21	32	30	16	1
5,Si2	32	39	26	22	32	21	17	<1
So	23	22	21	10	15	15	10	0
Ax	17	10	14	11	24	20	7	1
Number of isolates tested	194	356	347	265	313	328	187	

* NIAB (1998)

Both *V5* and *VTa2* decreased slightly in 1998, probably the delayed result of the demise of Mercia which carried the corresponding resistance factors. Virulence for *Pm3b* remained low, while *V17* and *VSo* also showed a decrease. There is no obvious selection for these virulence factors, as no current cultivars carry the corresponding resistance factors. There was a slight reduction in the level of *VSi2*. However, *MlSi2* is only found in **spring** wheats, of which few samples were received due to low infection levels. Virulence for *MlTo* also declined: there is only a small area of cultivars with this resistance, *viz* Spark and some spring wheat cultivars.

There were large reductions in the frequencies of *Vd*, *VBr* and *VAx*. However, this was probably due to a reduction in the number of samples of Cadenza. In 1996 and 1997, 13% of isolates tested were from Cadenza, contrasting with only 3% in 1998. Analysis of the non-corresponding virulence frequencies for 1997 and 1998 (not shown) revealed that *V2, 4b, 5, 6, 8* and *Ta2* were common on all cultivars, whether or not they carried the corresponding resistance factors. Conversely, *Vd*, *Br* and *Ax* were uncommon on cultivars that did not carry the corresponding resistance.

Frequency of pathotypes

The total number of pathotypes recorded continued the decline of the last six years (Table 3). As in previous years, there was one predominant pathotype in the wheat mildew population, *ie V2,4b,5,6,8,Ta2*. There was an increase in the frequency of pathotype *V2,4b,5,6,8*, probably related to the large increases in areas of cultivars carrying *Pm2*, *4b*, *6* and *8* compared with 1997 (Clarkson & Slater, 1998).

Table 3 Frequencies of the most commonly identified pathotypes in 1992 - 1998, as defined by the differential cultivars listed in Table 1.

	Frequency of pathotypes (%)						
Pathotype	1992	1993	1994	1995	1996	1997	1998
2,4b,5,6,8	14	6	8	8	4	3	9
2,4b,6,8,Ta2	0	1	2	3	1	2	6
2,4b,5,8,Ta2	2	4	4	2	1	<1	0
2,4b,5,6,8,Ta2	8	25	26	38	35	42	38
2,4b,5,6,8,Ta2,To,Br	3	4	5	6	4	7	5
2,4b,5,6,8,Ta2,Si2	0	0	2	4	6	4	5
2,4b,5,6,8,Ta2,Si2,So	4	8	6	8	4	7	4
2,4b,5,6,8,d,Ta2	2	2	7	5	5	3	6
2,4b,5,6,8,d,Ta2,To,Br,Ax	3	2	3	3	6	10	1
2,4b,5,6,8,d,Ta2,To,Br,Si2,So,Ax	1	1	2	<1	5	3	0
Number of pathotypes	78	78	71	57	59	44	35
Number of isolates	194	356	347	265	313	328	187

Complexity of isolates

The number of virulence factors carried by the wheat mildew isolates tested is shown in Table 4. Very few of the isolates tested had less than five virulence factors; the majority carried six factors, corresponding to the most common pathotype, *V2,4b,5,6,8,Ta2*.

Table 4 Number of virulence factors carried by the wheat mildew population in 1997 and 1998.

Number of virulence factors*	Frequency of isolates with each number of virulences (%)	
	1997	1998
0	0	0
1	0	0
2	0	0
3	0	0
4	1	2
5	7	18
6	45	44
7	9	15
8	16	11
9	4	4
10	13	5
11	2	0
12	3	2

* Corresponding to resistance factors in Table 1, except *Pm17* (Amigo) and *Pm3b* (Chul)

Table 5 gives the proportion of isolates tested which could potentially attack current winter wheat cultivars.

Table 5 The proportion of mildew isolates tested in 1998 able to infect winter wheat cultivars in Recommended List trials (1999 Recommended List cultivars in **bold**; mildew resistance ratings in brackets).

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Caxton (6)	100	**Riband (6)**	99
Charger (7)	100	Blaze (7)	96
Claire (4)	100	**Brigadier (5)**	96
Hereward (6)	100	**Buchan (6)**	96
Maverick (7)	100	**Equinox (5)**	96
Rialto (7)	100	Harrier (7)	96
Shango (3)	100	**Hussar (7)**	96
Abbot (7)	99	**Madrigal (6)**	96
Buster (4)	99	**Savannah (8)**	96
Cantata (7)	99	**Soissons (8)**	65
Chaucer (6)	99	**Spark (7)**	16
Consort (6)	99	Aardvark (8)	9
Malacca (7)	99	Cadenza (7)	7
Reaper (6)	99	**Shamrock (8)**	3

Most cultivars are at risk from infection by more than 90% of the mildew population, including the new Recommended List cultivars Buchan, Claire and Malacca. However, the NIAB resistance ratings indicate the level of non-specific resistance present in current cultivars. Many appear to have moderate non-specific resistance, *eg* Hereward and Consort, while others, *eg* Savannah and Soissons, have very good resistance.

Resistance Factors in New Cultivars

Specific resistance factors identified in current cultivars are shown in Table 6. Soissons carries an unknown specific resistance factor, which has been tentatively labelled *MlSs*. Shamrock also carries an unknown specific resistance factor. It is probable that Aardvark, which has Cadenza parentage, carries the Axona (*MlAx*) resistance, but this has yet to be confirmed.

Table 6 Specific mildew resistance factors of winter wheat cultivars. (1999 Recommended List cultivars in **bold**.)

None	*Pm2,4b,6*	*Pm4b,Pm6,Pm8 (Pm2?)*	*MlTo*
Charger	Cantata	**Brigadier**	**Spark**
Caxton	Chaucer	**Buchan**	
Hereward	**Consort**	**Hussar**	*MlAx (Mld,MlBr?)*
Rialto	**Malacca**	Harrier	Cadenza
	Riband	**Savannah**	
Pm2,Pm4b			*MlSs*
Claire	*Pm6,Pm8*	*Pm5,MlTa2*	**Soissons**
Maverick	Blaze	Mercia	
Shango	**Equinox**		*Unknown*
	Madrigal		Aardvark
Pm2,6			**Shamrock**
Abbot			
Buster			
Reaper			

CONCLUSIONS

Low infection levels in crops, due to wet spring and summer weather, led to decreased numbers of mildew samples being received in 1998. Virulence frequencies of *V2*, *V4b*, *V5*, *V6*, *V8* and *VTa2* were very high in the mildew population and corresponded well with the high acreages of cultivars carrying the corresponding resistance factors *Pm2*, *Pm4b*, *Pm6* and *Pm8*. Frequencies of *Vd*, *VBr* and *VAx* declined, compared with 1997 values, probably due to the lower numbers of Cadenza samples tested in 1998.

The total number of pathotypes recorded continued the decline begun in the early 1990s. As in recent years, one pathotype predominated in the population: *V2,4b,5,6,8,Ta2*. The majority of isolates carried 5 to 8 virulence factors, with 7% carrying 10 or more factors. Most isolates were potentially able to infect most current winter wheat cultivars, including the NIAB Recommended List newcomers Buchan, Claire and Malacca. The fourth new cultivar, Shamrock, appears to carry an unknown specific resistance factor. Soissons is also thought to possess a specific resistance factor, which has been tentatively designated *MlSs*. However, many current cultivars possess good **partial** resistance, which is reflected by their moderate-high NIAB resistance ratings.

REFERENCES

Clarkson, J.D.S. & Slater, S.E. (1998). Mildew of Wheat. *UK Cereal Pathogen Virulence Survey 1997 Annual Report,* pp 16-22.

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

NIAB (1998). Seed Production. Issue No 18, November 1998.

YELLOW RUST OF WHEAT

R.A. BAYLES and P.L. STIGWOOD

National Institute of Agricultural Botany, Cambridge

Yellow rust was widespread in 1998 and some 99% of isolates tested possessed virulence for WYR17. One new pathotype, WYV1,2,3,4,6,9,17, was identified. Adult plant tests confirmed the susceptibility of a large number of current cultivars to isolates possessing WYV17 and WYV6,17. However, the continued effectiveness of the resistance of a number of other cultivars was also highlighted.

1998 VIRULENCE SURVEY

Yellow rust was widespread in 1998, particularly in susceptible cultivars carrying the WYR17 resistance. The popularity of Brigadier declined sharply in comparison with 1997, but WYR17 cultivars continued to account for more than 25% of the total wheat acreage (Table 1).

Table 1 Popularity of winter wheat cultivars, 1998
(from seed certification statistics for England and Wales)

Cultivar	WYR Factors	NIAB Resistance Rating (1-9)	% acreage
Riband	13	6	20.1
Consort	CV	9	16.6
Brigadier	9,17	1	8.7
Reaper	17	4	8.4
Hereward	CV	7	7.7
Rialto	6,9	5	6.4
Hussar	9,17	5	3.6
Charger	? 6 + APR	9	5.0
Equinox	6,9,17	5	3.8
Abbot	17	6	3.2
Buster	R	9	3.1
Others	-	-	

94 isolates of *Puccinia striiformis* were tested in seedling virulence tests. These were obtained from 29 different cultivars (Table 2), mainly of the WYR 17 type. Isolates were received from most regions of the UK, including Scotland, Wales and Northern Ireland.

Table 2 1998 isolates - cultivars of origin

Variety	**WYR factors**	**% isolates**
Brigadier	9,17	26.6
Savannah	9,17	9.6
Reaper	17	6.4
Abbot	17	4.2
Blaze	9,17	4.2
Buchan	9,17	4.2
Hussar	9,17	3.2
Madrigal	6,9,17	4.2
Equinox	6,9,17	3.2
Riband	13	6.4
19 others	-	27.8

Table 3 Differential cultivars used in seedling virulence tests in 1998 (Differentials shown in italics were omitted)

Differential Cultivar	**WYR Factor**	**Gene**
Core set		
Chinese 166	WYR 1	Yr 1
Kalyansona	WYR 2	Yr 2
Vilmorin 23	WYR 3	Yr 3a+
Nord Desprez	WYR 3	Yr 3a+
Hybrid 46	WYR 4	Yr 3b, Yr 4b
Heines Peko	*WYR 2,6*	*Yr 6, Yr 2*
Heines Kolben	WYR 6	Yr6, (? Yr 2)
Lee	WYR 7	Yr 7
Reichersberg 42	*WYR 7*	*Yr 7 +*
Compair	WYR 8	Yr 8
Kavkaz x 4 Federation	WYR 9	Yr 9
Moro	*WYR10*	*Yr 10*
*Yr15/6*AvS*	*WYR15*	*Yr 15*
VPM 1	WYR17	Yr 17
Carstens V		CV
Avocet 'R'		Yr A +
Suwon 92 x Omar		So
Strubes Dickkopf		Sd
Spaldings Prolific		Sp
Additional set		
Madrigal	WYR 6,9,17	Yr6+Yr9+Yr17
Parade	WYR R	

Isolates were tested for virulence on seedlings of the differential cultivars listed in Table 3, using the methods described by Priestley, Bayles and Thomas, 1984.

Table 4 Virulence factor frequency % (from natural infection)

	'84	'85'	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98
WYV 1	75	76	78	87	68	62	85	91	88	89	65	90	97	100	99
WYV 2	100	100	100	100	100	100	100	100	100	98	100	99	97	100	99
WYV 3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 4	31	45	70	47	78	97	91	86	86	89	86	67	59	47	79
WYV 6	64	90	96	89	72	57	69	64	88	68	41	35	16	1	7
WYV 7	3	3	22	8	6	2	9	19	7	8	4	0	3	7	4
WYV 8	0	*	*	*	*	*	*	0	0	0	0	0	0	0	0
WYV 9	31	3	4	5	66	99	94	88	76	84	94	95	97	99	99
WYV17												57	84	99	99
CV											75	55	9	13	1
YrA+															84
So															78
Sd															100
Sp															0
Parade									3	0	0	0	0	0	0
Madrigal													0	1	6
No. of isolates	36	29	23	52	71	156	67	42	77	63	49	83	32	138	94

Seedling virulence frequencies are given in Table 4. The frequencies of WYV 1, WYV 2, WYV 3, WYV 9 and WYV 17 remained at, or close to, 100%. The frequency of WYV 4 increased markedly compared with 1997, to reach 79%. WYV 6 and virulence for CV remained at extremely low levels. Virulence for YrA+, So and Sd were detected at high frequencies. No virulence was detected for Sp.

Disregarding virulence for the newly introduced differentials for YrA+, So, Sd and Sp, the most common pathotypes were WYV1,2,3,4,9,17 (76%, compared with 36% in 1997), and WYV 1,2,3,9,17 (16% compared with 45% in 1997). Six isolates carried the virulence combination WYV6,9,17 and were virulent on Madrigal. One new pathotype was firmly identified, WYV1,2,3,4,6,9,17 and a second, WYV1,2,3,4,6,7,9,17, is awaiting confirmation.

ADULT PLANT TESTS

11 isolates from the 1997 survey (Table 5) were tested for virulence on adult plants of 33 cultivars in Polythene tunnels and on seedlings of the same cultivars. The isolates were chosen on the basis of their seedling virulence phenotypes and the cultivars from which they had been collected.

Table 5 Isolates of *Puccinia striiformis* used in adult plant tests

Isolate code	Source		WYV Factors
	Cultivar	Location	
97/7	Brigadier	Gloucestershire	1,2,3,9,17
97/77	Consort*	Leicestershire	1,2,3,9,17
97/88	Brigadier	Devon	1,2,3,9,17
97/102	Hunter*	Oxfordshire	1,2,3,9,17
97/141	WC.33.16.1B	Lincolnshire	1,2,3,9,17
97/20	Hussar	Cambridgeshire	1,2,3,4,9,17
97/79	Savannah	Lincolnshire	1,2,3,4,9,17
97/131	Abbot	Lincolnshire	1,2,3,4,9,17
97/136	Hussar	Northumberland	1,2,3,4,7,9,17
97/105	Madrigal	Lincolnshire	1,2,3,6,9,17
97/140	Shamrock	Lincolnshire	2,3,4,6,CV

* varieties as stated by sampler; probably mistaken identity

Adult plant polythene tunnel test results are given in Table 6.

The first eight isolates (97/7 to 97/131) all carried virulence for WYR9,17, but not for WYR6. These isolates gave high levels of infection on cultivars possessing WYR17 and WYR9,17, but generally low infection levels on cultivars known to carry WYR6 in combination with WYR17 or WYR9,17. The slight to moderate infection on Madrigal and Equinox in tunnels inoculated with certain of these isolates was due to contamination by a virulent pathotype during epidemic development. The cultivar Malacca was resistant to all isolates as an adult plant, although seedling tests indicated that it may carry WYR17.

Isolate, 97/136, was virulent on the cultivar Brock (WYR7,14), in addition to WYR9,17, cultivars. This is the first confirmation of the WYV7,9,17 virulence combination in adult plant tests.

Isolate 97/105 gave moderate to high levels of infection on Aardvark, Equinox and Madrigal, all cultivars with the WYR6,17 or WYR6,9,17 resistance combinations.

Isolate 97/140, which was virulent on Carstens V in seedling tests, gave moderate levels of infection on Hereward and Spark, cultivars with resistance derived from Carstens V. However, Consort and Shamrock, which are also believed to owe their resistance to Carstens V, remained resistant.

Apostle, Buster, Cadenza, Charger, Claire and Hunter maintained their resistance to all isolates. Buster and Cadenza have resistance of the 'overall' type, which is effective at both seedling and adult plant stages, while the resistance of the other cultivars is of the 'adult plant' type.

Virulence for the adult plant resistance WYR12 appeared to be absent. However, virulence for adult plant resistances WYR13 and WYR14 was common, as shown by the almost universally high level of infection on Riband and Hobbit. These resistances are unlikely to prove useful against the current yellow rust population.

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 6 Adult plant tests 1998. % leaf area infected with yellow rust (mean of 4 assessments)

Cultivar	Isolate: WYR	97/7	97/77	97/88	97/102	97/141	97/20	97/79	97/131	97/136	97/105	97/140
		Virulence in seedling tests given in Table 5.										
Abbot	17	9	12	10	7	7	13	12	14	15	7	1
Cantata	17	11	7	11	10	3	6	12	8	7	10	2
Chaucer	17	18	20	16	14	4	18	17	28	22	14	4
Maverick	17	37	26	24	22	20	30	22	21	32	20	7
Reaper	17	29	22	18	17	20	22	22	33	28	14	13
Blaze	9,17	41	17	10	14	14	32	35	22	28	16	15
Brigadier	9,17	52	43	52	49	43	53	50	55	49	33	30
Buchan	9,17	38	26	23	16	17	29	23	29	31	14	14
Harrier	9,17	26	24	15	17	14	26	28	26	27	14	13
Hussar	9,17	15	10	8	11	4	19	23	21	15	11	4
Savannah	9,17	17	16	14	14	12	18	19	16	19	11	10
Aardvark	6,9,17	0	0	0	1	1	1	0	0	1	8	0
Equinox	6,9,17	4	4	2	1	8	3	1	3	4	13	4
Madrigal	6,9,17	14	8	15	1	22	16	6	6	23	40	2
Malacca	?17 +APR	0	0	0	0	0	0	0	0	0	0	0
Caxton	6	1	0	1	1	0	1	1	1	2	9	2
Shango	6	4	4	4	0	0	2	1	1	6	11	6
Rialto	6,9	4	2	3	1	9	6	1	2	11	12	4
Consort	CV+	0	0	1	1	0	0	0	0	0	1	0
Hereward	CV	0	1	1	3	0	0	1	0	0	0	13
Shamrock	CV	1	0	0	0	0	0	0	0	0	1	1
Spark	CV+	1	1	2	2	0	1	1	1	1	5	10
Apostle	2,6,+APR	0	0	0	0	0	0	0	0	0	0	0
Buster	R Par	0	0	0	0	0	0	0	0	0	0	0
Cadenza	R Ton	0	1	1	1	0	0	0	0	0	1	0
Charger	?6+APR	0	0	1	0	0	0	0	0	0	2	1
Claire	Rx+APR	0	0	0	0	0	0	0	0	0	0	0
Hunter	6,9,+APR	0	0	0	0	0	0	0	0	0	1	0
Soissons	?3	8	7	7	8	0	14	11	9	11	9	2
Mega	12	1	0	3	3	0	1	1	1	2	2	0
Riband	13	16	14	10	10	7	12	11	12	14	10	2
Hobbit	14	21	20	22	17	10	24	20	26	25	14	24
Brock	7,14	0	0	0	1	0	1	1	0	11	0	0

BROWN RUST OF WHEAT

E.R.L. JONES

Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion, SY23 3EB, U.K.

Seedling tests with the 1998 isolates identified virulence, at different frequencies, to all the standard differential cultivars. Resistances conferred by some of the Thatcher backcross Lr lines remained effective. Adult plant tests in field nurseries identified several cultivars as having high levels of resistance. Likewise, in controlled environment tests, several of the cultivars carried effective resistance although the isolates differentiated some of them.

GLASSHOUSE SEEDLING TESTS WITH 1998 ISOLATES

The 49 samples of wheat brown rust received in 1998 were an increase on those received in recent seasons when in 1995, 1996 and 1997 only 19, 1 and 4 samples were received respectively. The rust-infected leaves were all collected from winter wheat cultivars with a large proportion (60%) coming from the Cambridge area. The geographical origins of the samples are given in Table 1.

Table 1 Geographical origins of the 1998 wheat brown rust samples.

Location (MAFF Region)	Number of samples
East Anglia	31
South-east	8
East Midlands	3
West Midlands	2
Yorkshire and Humberside	2
South-west	1
North	1
Wales	1

Isolates of *Puccinia recondita* were cultured from 43 of the leaf samples and tested on a set of differential cultivars which comprised the standard WBR cultivars and cv. Thatcher backcross lines carrying different Lr resistance factors. Eight newly-introduced spring and winter wheats were tested against some of the isolates (Table 2). Plants were grown and inoculated under standard conditions and, following incubation in dew simulation chambers at 15°C, were transferred to either of two post-inoculation environments, namely a low temperature regime (10°C and 12 h photoperiod) or a high temperature regime (25°C and 16 h photoperiod).

Table 2 Differential cultivars

Standard differential cultivars (WBR-factor)	Thatcher Lr lines		Spring and winter cultivars
Clement (1)	Lr 1	Lr 15	Imp
Fundin (2)	Lr 2a	Lr 17	Raffles
Norman (2)	Lr 2b	Lr 19	NCF 19606
Hobbit (2)	Lr 2c	Lr 20	Buchan
Sappo (3)	Lr 3	Lr 21	Malacca
Maris Halberd (4)	Lr 3bg	Lr 23	CPB TW47
Gamin (6)	Lr 3ka	Lr 24	Cockpit
Sterna (7)	Lr 9	Lr 26	Napier
Sabre (7)	Lr 11	Lr 28	
Armada (0)	Lr 13	Lr 37	
	Lr 14a		

Results

Isolate:cultivar interactions were classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4). In cultivars with temperature-sensitive resistance factors, interactions were classified as susceptible only if that reaction was expressed at both temperatures. The virulence combinations detected and their frequencies compared with those identified from 1990-1995 are given in Table 3. The frequencies of individual virulences over the same period are given in Table 4.

The increased frequency, identified in 1995, of isolates carrying virulence to only one or two of the differential cultivars was confirmed in the 1998 isolates when 66% of them failed to combine more than two virulence factors.

The further decline in WBV-1 isolates (Table 4) seen in 1998 reflects the decreased deployment of the corresponding resistance factor, WBR-1, in current cultivars compared to the early part of the decade.

Virulence compatible with the temperature-sensitive resistances (WBR-7) of cvs Sabre and Sterna was found in 3 isolates at both the high and low temperature regimes. WBV-7 has remained at a relatively low frequency in the pathogen populations since it was first identified in 1990.

Of the new cultrivars, the spring wheats Raffles and Imp and the winter wheats Malacca and Cockpit were susceptible to all the isolates. Cultivar NFC 19606 was susceptible to 9 isolates, resistance in the remainder being expressed at the higher temperature only to some isolates. Cultivars Buchan, CPBT W47 and Napier responded similarly to the isolates. They were resistant at 25°C but were susceptible to some isolates at 10°C.

The reactions of the Thatcher -Lr backcross lines to the 1998 isolates are given in Table 5.

Table 3 Virulence combinations and their frequencies identified from the 1998 isolates compared with the period 1990-1995

WBV formula	Frequency						
	1990	1991	1992	1993	1994	1995	1998
6	0.02	0	0.06	0.04	0.3	0.22	0.18
1,6	0	0	0	0	0.03	0.11	0.05
2,6	0.27	0.06	0.12	0.09*	0	0.22	0.37
6,7	0	0	0	0	0.03	0	0.02
1,2,6	0.67	0.82	0.76	0.75*	0.58	0.34	0.33
1,3,6	0	0	0	0.02	0	0	0
1,2,6,7	0.04†	0	0	0	0	0	0
1,2,3,6	0	0	0	0.06	0	0	0
1,2,4,6	0	0.06	0	0	0	0	0
1,2,6,7	0	0	0	0.04□	0.06	0.11	0.05
1,2,3,4,6	0	0.06	0.06	0	0	0	0
Number of isolates tested	51	18	17	53	39	18	43

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

Table 4 Virulence frequencies corresponding to each differential cultivar (1990-1995 and 1998)

Differential cultivar	WBR factor	Frequency						
		1990	1991	1992	1993	1994	1995	1998
Clement	1	0.67	0.94	0.82	0.87	0.67	0.55	0.43
Fundin	2*	0.98	1.00	0.94	0.83	0.64	0.67	0.75
Norman	2*	0.98	1.00	0.94	0.94	0.49	0.55	0.65
Hobbit	2*	0.98	1.00	0.94	0.94	0.41	0.44	0.61
Sappo	3*	0	0.06	0.06	0.08	0	0	0
Halberd	4*	0	0.11	0.06	0	0	0	0
Gamin	6†	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Sterna	7*	0.04	0	0	0.04	0.08	0.11	0.07
Sabre	7*	0	0	0	0.02	0.08	0.11	0.07
Armada	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of isolates		51	18	17	53	39	18	43

* temperature sensitive †adult plant resistance

Table 5 Virulence frequencies corresponding to each Thatcher-Lr backcross line to 1998 isolates of *Puccinia recondita* at two temperatures, 10°C and 25°C

Reaction Profile		Thatcher line (Lr gene)										
10°C	25°C		1	2a	2b	2c	3	3bg	3ka	9	11	13
R/MR	R/MR		0.44	0.32	0.17	0.09	0.58	0.58	0.83	0.48	0.02	-
R/MR	MS/S		-	-	-	-	-	-	-	0.02	-	-
MS/S	R/MR		0.56	0.68	0.66	0.39	0.35	0.35	0.10	0.50	0.02	-
MS/S	MS/S		-	-	0.17	0.52	0.07	0.07	0.07	-	0.96	1.00
		14a	15	17	19	20	21	23	24	26	28	37
R/MR	R/MR	-	0.96	-	1.00	1.00	0.80	-	1.00	0.57	0.57	-
R/MR	MS/S	0.02	-	-	-	-	-	-	-	-	-	-
MS/S	R/MR	-	-	0.96	-	-	0.18	1.00	-	-	0.36	-
MS/S	MS/S	0.98	0.04	0.04	-	-	0.02	-	-	0.43	0.07	1.00

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

Several of the Lr lines carry temperature-sensitive resistances which were overcome by varying numbers of the 1998 isolates at the low temperature regime of these tests (10°C).

The resistances of the Lr3 lines were overcome by 3 isolates, these being the ones which were virulent on cvs Sabre and Sterna (WBR-7). Resistance conferred by Lr3ka was effective against a greater number (83%) of the 1998 isolates at 10°C than either Lr3 or Lr3bg (48%). The lines Lr15 and Lr17 were susceptible to two of the WBV-7 isolates, WBRS-98-20 and WBRS-98-30. They were resistant to the remaining isolates although resistance was expressed only at the higher temperature by Lr17. Resistance conferred by Lr21 was also overcome by WBRS-98-20, cultured from the spring wheat cv. Chablis, and, although it was effective against the other isolates, it was effective only at 25°C against some. Line Lr14a, like cv. Fundin (WBR-2), was susceptible at 10°C to all but one isolate, WBRS-98-22.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Winter and spring wheat cultivars, including those on the current NIAB Recommended List and the standard differential cultivars, were sown in each of two nurseries. The nurseries were inoculated with one or other of the following isolates of *P. recondita*.

Isolate	Origin
WBRS-97-1	cv. Riband, Unknown
WBRS-97-3	cv. Chablis, Lincolnshire

Cultivar:isolate interactions were assessed on infection levels (% area infected) as well as on reaction type on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4).

Results

These are summarised in Table 6. Reasonable levels of disease built up during the season on the susceptible cultivars. Several of the cultivars were resistant and many of these are grouped together (Group 13). Other cultivars have been classified into groups not only on the basis of their responses to the 2 isolates in 1998 tests but also on data from previous years' tests. It should not be interpreted that cultivars within a group carry a common resistance factor(s).

The differential cultivars Clement (WBR-1), Fundin (WBR-2), Norman (WBR-2), Hobbit (WBR-2), Sterna (WBR-7) and Sabre (WBR-7) were susceptible to isolate WBRS-97-1 although it failed to infect them in 1997 seedling tests. This isolate also overcame the adult plant resistances of cvs Huntsman (WBR-5), Gamin (WBR-6) and Avalon (WBR-9) as well as those of cultivars in Group 10. Isolate WBRS-97-3, which was identified as carrying virulence factors 1, 2 and 7 in 1997 seedling tests, failed to infect cultivars carrying WBR-7 (Group 7). It did, however, infect cv. Sappo (WBR-3) although this differential had been classified as resistant (susceptible at 25°C; resistant at 10°C) to it in 1997 seedling test.

It may be that the nurseries became contaminated with naturally-occurring pathotypes.

CONTROLLED ENVIRONMENT TESTS

Winter and spring wheat cultivars were grown in a spore-proofed glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with one of each of the following isolates:

Isolate	Origin	Virulence factors identified in seedling tests
WBRS-98-1	cv. Riband, Kent	6
WBRS-98-20	cv. Chablis, Cambridge	1,2,6,7
WBRS-98-47	cv. Lynx, Suffolk	1,2,6

Following incoulation plants were incubated in dew simulation chambers at 15°C for 16 h and then transferred to either of two environments, namely a low temperature regime (10°C and 12 h photoperiod) or a high temperature regime (25°C and 16 h photoperiod).

Results

These are given in Table 7. Assessments of flag leaf infection were made on reaction type and classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4) and were made 10 days post-inoculation at 25°C and 26 days post-inoculation at 10°C. The majority of the cultivars expressed resistance to one or more of the isoltates and are grouped within the table on the basis of their patterns of response to the three isolates. It should not be interpreted that cultivars within a group carry a common resistance factor(s).

Group 1: Cultivars resistant, although some displayed low levels of a susceptible reaction type (3-4).

Group 2: Cultivars were susceptible to WBRS-98-20 which was identified in seedling tests as carrying virulence factors 1, 2, 6 and 7. Previous tests have identified cv. Chablis as carrying WBR-7 and cv. Rialto as carrying WBR-1 although the latter was resistant to isolate WBRS-98-47 which also carries WBV-1. Cultivar Savannah was resistant in 1998 field isolation nurseries to an isolate, WBRS-97-1, identified in those tests as carrying virulence factors 1, 2, 6 and 7 in common with isolate WBRS-98-20 to which it was susceptible. The Thatcher backcross line, Lr37, whose resistance is expressed at later growth stages is included in this group.

Group 3: The adult plant resistances of the cultivars were effective against isolate WBRS-98-1, resistance being expressed at 10°C only.

Group 4: The temperature-sensitive resistances of the cultivars were effective at 10°C but overcome at 25°C, except for cv. Imp which expressed resistance at the higher temperature to isolate WBRS-98-1.

Table 6 †Percentage infection of spring and winter wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries

Cultivar [NIAB rating]		Group	WBR factor	Isolate	
				WBRS-97-1	WBRS-97-3
Clement		1	1	6	7
Rialto	[5]			3	9
Fundin		2	2	13	13
Norman			2+	6	5
Hobbit			2+	9	2
Sappo		3	3	2 MS	10
Halberd		4	4	0.1 MS	0
Huntsman		5	5 APR	24	26
Mercia			APR	12	16
Gamin		6	6 APR	15	1
Sterna		7	7	10	0.2
Sabre			7	9	1
Chablis	[8]			3	Trace
Shiraz	[9]		7+	0	0
Ranger		8	8 APR	2	2
Avans			OR ?	0.5	0
Kinsman				Trace	Trace R
Avalon		9	9 APR	30	2
Buster	[2]		APR	40	4
Riband	[3]			4	4
Spark	[8]	10	APR	15	0.1
Hereward	[7]		APR	6	0
Consort	[6]		APR	7	0.1
Soissons	[2]		APR	23	3
Brigadier	[9]	11	OR	0	0.4
Hussar	[9]		OR	0	0
Beaufort			OR ?	0	0

Table 6 (continued)

Cultivar [NIAB rating]		Group	WBR factor	Isolate	
				WBRS-97-1	WBRS-97-3
Maverick		12	APR	0.7	0
Reaper	[9]			0.5	0.1 MS
Cadenza				1	0
Chaucer			APR	0.4	0.7
Cantata	[8]		APR	3	0.4
Caxton				6	0.3
Charger	[8]			5	0
Imp	[4]		APR	3 MS	Trace MS
Paragon	[(9)]		APR	1	0
Raffles	[(6)]		APR	8	0
Fury				8	3
Blaze		13	OR	0	0
Abbot	[9]			0	0
Equinox	[9]		OR	0	0
Axona	[8]		APR	0	0
Savannah	[9]		OR	0	0
Harrier			OR	0	0
Madrigal	[9]		OR	0	0
Samoa	[(8)]			0	0
Baldus	[9]		APR+OR	0	0
Arina		14		23	23

† Mean of 3 replicates, final 2 assessment dates.
All reaction types susceptible unless stated.
MS = mixed susceptible; R = resistant
APR = adult plant resistance; OR = overall resistance
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 7 Adult plant †reactions of winter and spring wheats to specific isolates of *P. recondita* at 10°C and 25°C

Isolate			WBRS-98-1		WBRS-98-20		WBRS-98-47	
Incubation Temperature °C			10	25	10	25	10	25
Cultivar [NIAB rating]		Group						
Aardvark	[9]	1	R	R	R	R	R	R
Buchan	[9]		R	R	R	R	R	R
Equinox	[9]		R	R	R	R	R	R
Claire	[9]		R	R	R	R	R	R
Madrigal	[9]		R	R	R	MR	R	R
Hussar	[9]		R	R	R	MR	R	R
Abbot	[9]		R	R	R	MR	R	R
Harrier			R	R	MR	MR	R	R
Reaper	[9]		MR	MR	MR	MR	MR	MR
Axona	[8]		R	MR	R	MR	R	MR
Chablis	[8]	2	MR	MR	S	S	MR	MR
Savannah	[9]		R	R	S	S	R	R
Shamrock	[6]		R	MR	S	S	R	MR
Riband	[3]		MR	MR	S	S	MR	MR
Rialto	[5]		R	R	S	MS	R	MR
Lr37			MR	R	MS	S	MR	MR
Buster	[2]	3	R	MS	S	S	S	S
Spark	[8]		R	MS	S	S	MS	MS
Lr13			MR	MS	MS	S	MS	MS
Imp	[4]	4	MR	MR	MR	S	MR	MS
Raffles	[(6)]		R	MS	MR	S	MR	MS
Paragon	[(9)]		MR	S	MR	S	MR	MS

† Reactions classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4).
R = resistant; MR = mixed resistant;
S = susceptible; MS = mixed susceptible

BROWN RUST OF WHEAT: NIAB ADULT PLANT TESTS

J.D.S.CLARKSON and S.J.MANN

National Institute of Agricultural Botany, Cambridge

METHODS

Four spreader beds of winter wheat cultivars were inoculated with different isolates of brown rust (*Puccinia recondita*), as part of the Recommended List testing programme funded by the Home-Grown Cereals Authority. Three spreader beds and one open polythene tunnel of spring wheat cultivars were similarly employed. Methods used were similar to those of the previous year (Clarkson & Mann, 1998), although isolate mixtures were used for the third and fourth isolate tests in 1998. Details of the isolates are shown in Table 1 and the test results, expressed as the mean infection in two replicates assessed on five occasions (spreader beds) or three replicates assessed four times (polythene tunnel), are given in Table 2. The WBR Group and Factors (Jones, 1998, 1999) and probable *Lr* genes (R. McIntosh, Cobbity, pers. comm.) of cultivars are also shown in Table 2.

Table 1 Isolates of brown rust used in adult plant tests, NIAB Cambridge, 1998

Isolate no.	(probable virulence)	Origin of isolate
WBRS-97-3	(WBV 1,2,7)	Chablis, Lincs, 1997
WBRS-95-19	(WBV1,2,5,7)	Chablis, Suffolk, 1995
WBRS-96-1	(WBV 3,4,6)	Caxton, Suffolk, 1996
WBRS-94-50	(WBV 1,2,6)	Flame, Norfolk, 1994

RESULTS

Good infection levels were established in 1998, due to earlier and repeated inoculation of cultivars. In the resistant winter wheat cultivars (NIAB rating 9), no or only a trace of brown rust was found with the exception of low levels of isolate 97-3 on Chaucer and Hussar and of 94-50 on Harrier. These were possibly positive cultivar/isolate interactions. It would appear that the WBR OR (Overall Resistance) factor and the Lr13+17 and Lr26+37 gene combinations remain effective. Moderate infection occurred on Virtue, although its last recorded rating (9) was in 1984 and virulence for this cultivar has been noted since the early 1990s (Mitchell, 1995). Moderate levels of infection by all isolates were also found on Caxton, Charger and Pastiche: all rating 8 cultivars. A notable feature of the 1998 growing season was the unexpectedly low levels of brown rust in crops of Rialto, despite severe infection in other susceptible cultivars, *eg* Riband, Buster and Soissons, and a similar trend was recorded in these tests.

The resistant (rating 8 or 9) spring wheat cultivars Baldus, Chablis and Samoa all exhibited low levels of infection by isolates 94-50 and 97-3. Moderate infection developed on the susceptible cultivars Alexandria and Fury.

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REFERENCES

Clarkson, J.D.S. & Mann, S.J. (1998). Brown rust of wheat: NIAB adult plant tests. *U.K. Cereal Pathogen Virulence Survey 1997 Annual Report*, pp 41-42.

Jones, E.R.L. (1998). Brown rust of wheat. *U.K. Cereal Pathogen Virulence Survey 1997 Annual Report*, pp 30-40.

Jones, E.R.L. (1999). Brown rust of wheat. *U.K. Cereal Pathogen Virulence Survey 1998 Annual Report*, pp 33-41.

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

Table 2 Reactions of winter and spring wheat cultivars to field infection by brown rust isolates, 1998
(by decreasing disease resistance rating)

	Cultivar	NIAB rating#	WBR Group	WBR Factor	Lr gene(s)	% infection 94-50	97-3	95-19 + 96-1	Mixture^
WW	Aardvark	*9*				0	0	0	n/t
	Abbot	9	13			0	0	0.1	n/t
	Blaze	*9*	13	OR		0	0	0	n/t
	Brigadier	9	11	OR	26+37	0	0	0	n/t
	Buchan	9				0	0	0	n/t
	Cadenza	*9*	12		13	1.1	0.7	1.5	n/t
	Chaucer	*9*	12	APR		0.2	9.0	1.5	n/t
	Claire	9				0	0	0	n/t
	Equinox	9	13	OR		0	0	0	n/t
	Harrier	*9*	13	OR		9.5	0	0	n/t
	Hussar	9	11	OR	26+37	0	4.6	0	n/t
	Madrigal	9	13	OR		0	2.5	0	n/t
	Maverick	*9*	12	APR		0	0.1	0	n/t
	Reaper	9	12		13+17	0	0.1	0	n/t
	Savannah	9	13	OR		1.0	2.5	0	n/t
	Virtue	*9*			13+Apr b	13.0	19.5	18.0	n/t
	Wellington	*9*				0	0.1	0	n/t
	Cantata	*8*	12	APR		1.5	1.8	5.5	n/t
	Caxton	*8*	12			16.5	15.8	16.5	n/t
	Charger	8	12			12.5	13.5	6.2	n/t
	Malacca	8				0.8	1.0	2.6	n/t
	Pastiche	*8*			13+Apr b	11.0	16.5	24.8	n/t
	Slejpner	*8*			13+26	0	0	0	n/t
	Spark	8	10	APR	13+Apr b	6.5	8.3	6.0	n/t
	Hereward	7	10	APR	13+Apr b	8.5	7.5	5.7	n/t
	Shango	*7*				4.5	10.2	5.3	n/t
	Consort	6	10	APR	13	14.0	14.1	11.0	n/t
	Shamrock	6				10.5	10.0	7.2	n/t
	Avalon	*5*	9	9, APR	Apr a	25.0	21.5	15.7	n/t
	Huntsman	*5*	5	5, APR	13	45.3	44.5	45.9	n/t
	Rialto	5	1			7.5	4.6	4.0	4.0
	Haven	*3*			13+26	13.2	7.2	2.1	n/t
	Mercia	*3*	5	APR	13+Apr b	n/t	n/t	n/t	42.0
	Riband	3	9		3+13	27.0	27.8	29.6	13.7
	Buster	2	9	APR	13	36.0	32.5	29.5	n/t
	Soissons	2	10	APR	(sus)	30.7	27.1	29.3	n/t
SW	Avans	*9*	8	OR?		0	0	0	0
	Baldus	*9*	13	APR,OR		1.5	1.5	0	0
	Paragon	(9)	12	APR		0	0.7	0	0
	Shiraz	9	7	7+?	3	0	0	0	0
	Axona	8	13	APR		0	0	0	0
	Chablis	8	7		3	0.1	2.5	0	0.1
	Samoa	*(8)*	13			1.0	1.8	1.0	0.4
	Raffles	*(6)*	12	APR		4.7	5.1	4.5	1.8
	Imp	5	12	APR		3.8	4.1	1.0	0.1
	Alexandria	*3*				6.5	18.0	4.0	2.8
	Fury	*2*	12			6.2	14.3	12.0	6.2

1-9 scale: 9=resistant (**1999 NIAB Recommended List rating** or *last recorded rating* given)
^ Mixture of 94-50, 97-3, 95-19 + 96-1
n/t not tested

MILDEW OF BARLEY

S. E. SLATER and J. D. S. CLARKSON

National Institute of Agricultural Botany, Cambridge

There has been little change in the barley mildew population in recent years. Virulences corresponding to the resistance factors in the most common cultivars, together with some virulence factors for which there is no longer selection, remained at high frequencies. The population continues to be heterogenous. Most of the pathotypes carried six or more virulence factors. The majority of winter cultivars on the Recommended List are potentially at risk of infection by a large proportion of the mildew population. In tests, some isolates consistently gave increased levels of infection on Apex and Riviera, which carry *mlo* resistance. It is possible that there has been some adaptation in the mildew population to the *mlo* resistance factor.

INTRODUCTION

Due to a mild winter and early spring, mildew overwintered well and infection levels were high in January, February and March. However, following heavy rain in many parts of the country in April, spread of the disease was arrested. Consequently, infection levels of powdery mildew in most crops were low during the summer of 1998 and hence fewer samples were received this year.

METHODS

Virulence survey

As in previous years, random samples of airborne spores were collected in March, June and October; samples were also collected in January in 1998. Samples were taken from infected trial plots, mainly from Cambridge, early in the season. Few samples were received later in the season and most of these failed to produce viable spores.

Isolates from infected leaves were collected from the following 3 locations:

NIAB, Cambridge	136	isolates
Ashford, Kent	5	
Bridgets, Hants.	5	
Total	**146**	

Isolates were collected from the following 8 spring and 27 winter cultivars:

Spring cultivars

Cooper	6	isolates	Optic	4	isolates	Derkado	2	isolates
Riviera	6		Chariot	2		Prisma	2	
Delibes	4		Dandy	2				

Winter cultivars

Regina	12 isolates	Gleam	10 isolates	Vertige	10 isolates
Fanfare	10	Halcyon	10	Rifle	9
Gaelic	10	Manitou	10		

Isolates were also collected from Angela, Angora, Baton, Epic, Flute, Hanna, Heligan, Intro, Jewel, Linnet, Melanie, Muscat, Pastoral, Pearl, Peridot, Pipkin, Puffin, Spirit (2 isolates each) and Fighter (1 isolate).

Isolates were tested for virulence on detached leaves of the differential cultivars listed in Table 1.

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

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

Virulence for mlo cultivars

In tests carried out in the spring of 1998 using isolates collected from the roof nursery in January, more colonies than expected were observed on Apex, the *mlo* differential, and Riviera. To investigate this phenomenon, a selection of isolates which gave higher than expected levels of infection on Apex and Riviera in the differential tests (designated Apex +) was compared with isolates from the same source, which had showed no infection on Apex and Riviera in the original tests (Apex x). The isolates were inoculated onto a range of cultivars believed to carry the *mlo* resistance factor. The test was carried out in September and repeated in December. Isolates collected from Recommended List trial plots at Cambridge were also included in the experiment.

RESULTS

Virulence

The results of the 1998 survey are shown in Table 2. The frequency of many of the virulence factors was similar in all populations. The higher levels of *Vh, Va6, Va9 and Va13* in the leaf isolates probably reflects the origin of these samples, as most of the leaf isolates tested were collected from winter cultivars, some of which carry the corresponding resistance factors. *Va7* was lowest in June but higher in the other months, corresponding to selection by winter cultivars only; the most popular winter barley, Regina, carries *Mla7*.

Table 2 Virulence frequencies in single colony isolates of barley mildew from infected leaves (leaf sample) and from random samples of airborne spores, and the area of barley cultivars with the corresponding resistance factors in 1998.

	Frequency of virulence factors (%)						
	Leaf sample		Random samples of airborne spores				
Virulence gene	All data	Non-corresponding virulence *	January	March	June	October	Area of corresponding resistance (%) #
Vh	71	68	67	49	62	59	9
Vra	100	100	100	100	100	100	32
Vg	99	99	95	98	95	99	15
V(CP)	95	95	94	92	94	97	15
Va6	43	41	31	27	34	22	6
VLa	78	77	60	78	79	72	1
Va12	83	80	73	72	78	84	17
Vk1	81	81	75	74	67	65	0
Va7	76	72	75	81	67	75	18
V(Ab)	51	47	48	43	65	70	14
Va1	55	52	40	43	50	46	2
Va9	38	35	35	38	18	25	1
vo	0	0	0	0	0	0	16
Va13	21	20	50	16	13	24	1
Va3	1	1	0	0	1	2	0
Number of isolates	146		201	200	97	99	

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

NIAB (1998)

VLa, *V(Ab)* and *Va1* were higher in June and lower in January, reflecting selection by spring cultivars only. There is selection for *Va12* throughout the year, as the corresponding resistance is carried by both winter and spring cultivars, *eg* Rifle (winter) and Optic (spring). This was reflected in similar frequencies for *Va12* in all populations.

The virulence frequencies for 1991-1998 are shown in Table 3. Generally, there has been little change in recent years. *Vh* has decreased slightly in the last two years. This is probably the result of a reduction in the area of cultivars carrying *Mlh*. In 1994, 20% of the winter barley area carried *Mlh*, *eg* Puffin, while in 1998 only 12% of the area carried this resistance.

Table 3 Virulence frequencies in barley mildew, 1991 to 1998.

Virulence gene	Virulence frequency (%) *							
	1991	1992	1993	1994	1995	1996	1997	1998
Vh	-	78	78	79	70	78	68	61
Vra	99	100	100	99	100	100	100	100
Vg	99	99	96	95	95	96	95	97
V(CP)	96	98	92	88	90	90	93	94
Va6	23	31	35	31	34	30	25	31
VLa	36	24	22	25	31	56	58	72
Va12	61	73	72	67	71	70	73	76
Vk1	80	77	75	72	72	76	71	73
Va7	78	78	76	69	73	76	73	76
V(Ab)	64	72	76	74	67	62	52	53
Va1	15	13	18	23	27	38	36	45
Va9	28	26	29	34	33	37	33	32
Va13	43	42	38	43	37	41	39	25
Va3	-	-	1	<1	<1	<1	1	1
Number of isolates	780	462	628	539	552	428	551	743

* Mean of leaf samples and random samples of airborne spores for each year. Data from Mitchell & Slater (1992, 1993, 1994, 1995), Clarkson & Slater (1996) and Slater & Clarkson (1997, 1998).

- No data

The frequencies of *Va6*, *Va12* and *Va7* have remained stable over the last few years, due to continuing selection. Regina, currently the most popular winter barley, carries *Mla7*, while Gleam (winter, *Mla6*) and Optic (spring, *Mla12*) represent significant proportions of the total barley area.

VLa and *Va1* have both increased in frequency, despite a decrease in the area of cultivars carrying the corresponding resistance factors. *MlLa* is represented solely by Cooper (1% in 1998), while *Mla1* occurs in only 2% of the barley area. Although there has been a decrease in the frequency of *V(Ab)* since the mid-1990s, the 1998 level remained similar to that of 1997. In the late 1980s, several popular cultivars (*eg* Triumph, Blenheim, Prisma) carried *Ml(Ab)*, exerting enormous selection pressure. Following a period with few *Ml(Ab)* cultivars, Optic (*Mla12,Ml(Ab)*) now represents 40% of the spring barley area.

Complexity of isolates

The complexity of the barley mildew population is shown in Table 4, expressed as the number of virulence factors carried by the isolates tested. The different sets of isolates were similar, with most isolates carrying six or more virulence factors.

Table 4 Number of virulence factors carried by isolates of barley mildew in 1998.

No. of virulence factors	Frequency of isolates with each number of virulences*				
		Random samples of airborne spores			
	Leaf samples	January	March	June	October
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	0	1	<1	0	0
4	0	2	1	2	0
5	2	5	4	7	4
6	7	13	10	12	9
7	16	15	21	13	12
8	16	22	25	16	27
9	16	18	16	16	20
10	27	17	18	25	21
11	10	9	2	4	6
12	4	2	1	3	0
13	2	0	<1	0	0
No. of isolates	146	200	200	97	99

* includes all virulences listed in Table 2.

Table 5 compares the complexity from 1991-1998. The population has become increasingly complex over the last few years, with a few isolates now carrying thirteen virulence factors.

Table 5 Comparison of the complexity of isolates collected from 1991 to 1998

Number of virulence factors	Frequency of isolates with each number of virulences*							
	1991	1992	1993	1994	1995	1996	1997	1998
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	<1	0	<1	0	<1	<1	0	0
3	1	<1	<1	0	<1	1	0	<1
4	1	<1	4	1	1	1	1	1
5	2	2	18	4	4	3	4	4
6	8	8	34	10	11	7	11	10
7	20	20	27	24	19	14	17	15
8	33	35	10	25	28	22	23	22
9	23	25	4	16	20	24	21	18
10	10	7	1	12	10	16	16	20
11	3	3	<1	4	5	10	4	6
12	<1	<1	0	2	1	8	2	2
13	0	0	0	0	0	3	<1	<1
Total number of isolates	780	463	628	539	552	428	551	743

* includes all virulences listed in Table 2

Frequencies of the most common pathotypes

The heterogenous nature of the barley mildew population is shown in Table 6. Over 300 pathotypes were detected in 1998, the highest since 1995. The commonest pathotypes were *Vh,Vra,Vg,V(CP),Va6,VLa,Va12,Vk1,V(Ab),Va1* (present in 6% of the population) and *Vh,Vra,Vg,V(CP),VLa,Va12,Vk1,Va7,V(Ab),Va1* (3%). 170 of the pathotypes identified were represented by a single isolate only.

Table 6 The number of pathotypes identified in 1995-1998

	Total number of isolates tested	Number of pathotypes
1995	552	298
1996	428	238
1997	551	277
1998	743	302

The current commercial barley cultivars select for a total of thirteen known virulence factors, 10 of these by more than 1% of the barley area. This contrasts with the more homogeneous wheat mildew population, where 91% of the wheat cultivars select for only four virulence factors (Clarkson & Slater, 1999).

Table 7 shows the proportion of the mildew population to which the current barley cultivars are potentially susceptible. Most of the winter cultivars have resistance matched by over 50% of the mildew population. Only the *mlo* cultivars have a NIAB rating of 9 and are completely resistant. However, although potentially at risk from a large proportion of the population, some winter barleys have good non-specific resistance, as indicated by their high NIAB rating, *eg* Angela and Pearl (rating 8).

Table 7 The proportion of mildew isolates tested in 1998 able to infect the barley cultivars in Recommended List trials (NIAB rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Halcyon (6)	100	Jewel (7)	73
Hanna (4)	100	Angela (8)	61
Heligan (4)	100	Melanie (5)	61
Intro (6)	100	Pearl (8)	58
Muscat (6)	100	Vertige (5)	49
Pastoral (3)	100	Manitou (5)	32
Fanfare (5)	94	Epic (7)	26
Regina (3)	76	Gleam (6)	26
Rifle (7)	76	Pipkin (2)	25
Flute (8)	73		
Spring cultivars	**Proportion (%)**	**Spring cultivars**	**Proportion (%)**
Optic (7)	47	Dandy (9)	0
Prisma (3)	47	Decanter (9)	0
Cooper (7)	39	Derkado (9)	0
Delibes (6)	28	Hart (9)	0
Century (9)	0	Landlord (9)	0
Chalice (9)	0	Riviera (9)	0
Chariot (9)	0	Static (9)	0

Virulence for *mlo* cultivars

The mean infection for the three groups of isolates tested is shown in Table 8.

Table 8 Percentage number of colonies, relative to Golden Promise, on *mlo* cultivars after inoculation with isolates previously giving varying levels of infection on Apex and Riviera.

	Source of isolates					
	Apex x		Apex +		mlo cvs	
	Test 1	Test 2	Test 1	Test 2	Test 1	Test 2
Chariot	0.2	1.4	2.8	3.2	6.7	0.2
Hart	0.2	0.6	1.8	1.0	1.2	0.6
Landlord	0	0.2	0.1	0.6	1.3	0.4
Riviera	0.2	1.0	1.0	2.3	1.5	2.2
Derkado	1.1	0.4	2.9	5.1	0.5	0.2
Chalice	8.6	5.0	14.0	6.4	14.4	8.2
Decanter	0	0	0.8	0.2	1.0	0.4
Static	0	0.1	0.6	0.2	0.9	0.4
Apex	3.1	1.3	2.3	2.0	6.0	1.1

In the first test, the highest levels of infection were produced by isolates from *mlo* cultivars. But, in the second test, the highest levels of infection were given by isolates designated Apex +. However, the lowest infection levels in both tests were given by Apex x isolates. In general, the cultivars ranked in the same order, whatever the source of the isolates, and in a similar manner in both tests.

Resistance factors in new cultivars

The specific resistance factors carried by cultivars in NIAB trials in 1998 are shown in Table 9.

Table 9 Specific resistance genes of barley cultivars (1999 Recommended List cultivars in **bold**)

None	**Halcyon** (W), **Hanna** (W)
Mlra	**Heligan** (W), **Intro** (W), **Muscat** (W), **Pastoral** (W)
Mlh,Mlra	**Angela** (W), Angora (W), **Melanie** (W)
Mlra,Mlg,Ml(CP)	**Fanfare** (W)
Mlh,Mlra,Mlg,Ml(CP)	**Pearl** (W)
Mlra,Mlg,Ml(CP),Mla6	**Epic** (W)
Mlh,Mlra,Mlg,Ml(CP),Mla6	**Gleam** (W)
Mlra,Mla12	Baton (W), **Rifle** (W)
Mlra,Mlg,Ml(CP),Mla12	Puffin (W)
Mlg,Ml(CP),Mla12	**Flute** (W), **Jewel** (W), Peridot (W)
Mla9	**Manitou** (W)
Mla7 (Mlra?)	**Regina** (W)
Mlra,Mlg,Ml(CP),Mla7	Spirit (W)
Mlh,Mlra,Mla7	**Vertige** (W)
Mla13	**Pipkin** (W)
Mla12,Ml(Ab)	NFC SB94-4 (S), **Optic** (S)
Mlg,Ml(CP),Mla12,Ml(Ab)	**Prisma** (S)
Ml(La),Mla1	**Cooper** (S)
Ml(Ab),Mla1	**Delibes** (S)
mlo	**Alexis** (S), **Century** (S), **Chalice** (S), **Chariot** (S), **Dandy** (S), **Decanter** (S), **Derkado** (S), **Hart** (S), **Landlord** (S), **Riviera** (S), **Static** (S)
Unknown	Fighter (W), Gaelic (W)

(W) winter cultivar, (S) spring cultivar

No new resistance factors or combinations have been identified for several years. The majority of spring barley cultivars entered into NIAB Recommended List trials continue to carry the *mlo* resistance. As yet, this resistance has not been detected in winter cultivars.

DISCUSSION

There has been little change in the barley mildew population over the last few years. Virulences corresponding to the resistance in the most popular cultivars, together with some virulence factors for which there is no longer selection, remained at high frequencies. Virulence for *Mlh*, *Mlra*, *Mlg* and *Ml(CP)*, which commonly occur in winter cultivars, was present in over 90% of the isolates. There has been continued selection for these virulence factors since the 1960s. The differences in the populations of airborne spores were related to the distribution of the corresponding resistance factors. Levels of *Va12* were similar in all populations, as *Mla12* is found in both winter and spring cultivars. *Va7* was highest in samples collected in the winter, reflecting the occurrence of *Mla7* in winter cultivars only; *V(Ab)* was highest in summer populations, due to selection from spring cultivars only.

The population continues to be heterogenous, consisting of many pathotypes most of which carry six or more virulence factors. None of the pathotypes was dominant, the commonest occurring in only 6% of the isolates. The majority of the winter cultivars on the Recommended List are potentially at risk of infection by a large proportion of the mildew population. Although some of these cultivars are very susceptible, others carry good non-specific resistance.

The spring barley area is dominated by cultivars with *mlo* resistance, which remains effective. However, it is possible that there has been a shift towards increased infection of *mlo* cultivars. In previous years, low levels of infection have occasionally been seen on *mlo* cultivars in the field but virulence has never been confirmed in laboratory tests. Differential tests sometimes exhibit infection on Apex but the reactions have not proved repeatable. This suggests that variable test conditions are the cause of the sporadic infections seen in tests and occasional infections in the field due to environmental factors. However, since the reactions of the isolates in the experiment were consistent with the classification in the original differential test, it is possible that there has been some adaptation in the mildew population to the *mlo* resistance factor.

No cultivars with new resistance factors have been entered into Recommended List trials.

REFERENCES

Clarkson, J.D.S. & Slater, S.E. (1996). Mildew of barley. *UK Cereal Pathogen Virulence Survey 1995 Annual Report*, pp 34-43.

Clarkson, J.D.S. & Slater, S.E. (1999). Mildew of wheat. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp 19-25.

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

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

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

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

NIAB (1998). Seed Production No.18 (November 1998).

Slater, S.E. & Clarkson, J.D.S. (1997). Mildew of barley. *UK Cereal Pathogen Virulence Survey 1996 Annual Report*, pp 31-39.

Slater, S.E. & Clarkson, J.D.S. (1998). Mildew of barley. *UK Cereal Pathogen Virulence Survey 1997 Annual Report*, pp 43-51.

MILDEW OF BARLEY IN NORTHERN IRELAND

P.C. MERCER and A. RUDDOCK

Applied Plant Science Division, Department of Agriculture, New Forge Lane, Belfast

Fifty-eight isolates were tested, 25 from spring barley and 33 from winter barley. Areas of the commonest cultivars were similar to the previous season. There was good general consistency for virulence %s both with the previous season and data from England and Wales. Pustules were isolated from cv. Riviera which proved capable of transfer to *cv.* Golden Promise and back to *cv.* Riviera and *cv.* Atem. However, the overall virulence frequency of *mlo* and combined virulence *mlo* and *VLa* remained low, although results from a fungicide trial comparing *cvs.* Riviera and Felicie with and without fungicide, showed a reduction in a low incidence of mildew with fungicide and a small but significant increase in yield

INTRODUCTION

Fifty-eight isolates of mildew were collected from a range of winter and spring barley cultivars and tested on the same 23 differential cultivars as used in the previous season. Isolates were obtained using Golden Promise trap plants from which single pustules were grown up on further Golden Promise plants before being transferred to the differential cultivars. A list of all the cultivars used for testing virulences of isolates and their genetic designations is shown in Table 2.

The most commonly sown cultivars in N. Ireland in the season 1997/98 are shown in Table 1. For the first time for many years the range of cultivars and the percentage they occupy are almost identical to the previous season. The % of cultivars carrying the *mlo* gene dropped slightly from 82% to 77%.

Table 1 Percentage use of barley cultivars in N. Ireland (1996/97)

Spring cultivars *(resistance genes)*	**%**	**Winter cultivars** *(resistance genes)*	**%**
Riviera (*mlo*)	53	Regina (*Mlra, Mla12*)	64
Dandy (*mlo*)	22	Pastoral (*Mlra*)	18
Delibes (*Ml(Ab), Mla1*)	8	Hanna (*none*)	11
Felicie (*Mlg, Ml(CP), Mla9*)	7	Jewel (*Mla12 + ?*)	3
Chariot (*mlo*)	2	Fighter(*Mlg,Ml(CP),Ml(Ab)*)	2

Table 2 Test cultivars for the detection of virulence groups

Cultivar	**Resistance gene**	**BMR group**
Golden Promise	none	0
Weihenstephan 37/136	*Mlh*	1a
Weihenstephan 41/145	*Mlra*	1b
Zephyr	*Mlg, Ml(CP)*	2
Midas	*Mla6*	3
Goldspear	*Mla6, MlLa*	3 + 4
Varunda	*MlLa*	4
Egmont	*MlLa, Mla12*	4 + 5
Dram	*MlLa, Mlk*	4 + 6a
Klaxon	*MlLa, Mlk, Mla7*	4 + 6a+ 6b
Atem	*MlLa, mlo*	4 + 9
Tyne	*MlLa, Mla13*	4 + 10
Hassan	*Mla12*	5
Hordeum 1063	*Mlk1*	6a
Porter	*Mla7*	6b
Lotta	*Ml(Ab)*	6c
Keg	*Mlk, Mla7*	6a + 6b
Triumph	*Mla7, Ml(Ab)*	6b + 6e
Delta	*Mla1*	7
Leith	*Mla9*	8
Apex	*mlo*	9
Digger	*Mla13*	10
Ricardo	*Mla3*	11

RESULTS

The frequencies of a range of single major genes and some of their combinations are shown in Table 3. There is generally a good level of consistency with the previous season (Mercer, 1998) and with figures from England and Wales (Slater and Clarkson, 1999). In 1997, the value for *Va3* appeared to be higher than for England and Wales, but this year's figure of 5% is more in line. The value for the combined virulence *Vla, Vla13* was very low compared with the last two years. Whether this is part of a trend or one-off variation is not clear. Again there were small percentages for *mlo* and combined virulence *VLa* and *mlo*, of 9% and 2% respectively. Spores from Riviera were inoculated on to *cv.* Golden Promise and spores from resulting pustules were inoculated back on to Riviera and Atem and produced pustules in both cases.

In a fungicide trial, comparing the effectiveness of the resistance of *cv.* Riviera and *cv.* Felicie with and without fungicides, a low incidence of mildew was observed on Riviera (Table 4), which was reduced further by the application of tebuconazole fungicide. There was also a small but significant increase in yield for both cultivars following fungicide application. No other disease of significance was observed. Although, the *mlo* resistance generally appears to be holding, there may be indications here of a small shift towards virulence.

Table 3 Frequencies of virulence alleles from isolates collected from barley crops from 1990 to 1998

Virulence gene	BMV group	Frequency of virulence alleles								
		1990	1991	1992	1993	1994	1995	1996	1997	1998
Vh	1a	na	na	na	na	na	na	na	75	60
Vra	1b	na	na	na	na	na	na	na	83	77
Vg, V(CP)	2	43	64	39	43	77	50	52	67	60
Va6	3	41	54	36	47	56	26	41	58	41
VLa	4	27	57	25	47	42	44	33	75	79
Val2	5	46	54	31	67	74	61	80	58	52
Vkl	6a	na	na	na	na	na	na	na	83	75
Va7	6b	na	na	na	na	na	na	na	75	41
V(Ab)	6c	na	na	na	na	na	na	na	(100)*	73
Val	7	20	14	14	40	22	41	7	(100)*	39
Va9	8	27	30	28	30	29	46	45	67	42
corresponding to *mlo*	9	na	na	na	na	na	na	na	8	9
Val3	10	14	46	25	27	37	19	38	50	29
Va3	11	na	na	na	na	na	na	na	17	5
Va6, VLa	3 + 4	67	39	36	30	50	22	33	67	41
VLa, Val2	4 + 5	27	50	47	30	53	24	33	67	31
VLa, Vk	4 + 6a	50	50	44	30	24	33	48	67	52
VLa and corresponding to *mlo*	4 + 9	0	0	0	0	0	4	0	0	2
VLa, Val3	4 + 10	na	na	3	0	11	6	35	25	3
Vk, Va7	6a + 6b	48	57	31	37	38	28	43	67	33
Va7, V(Ab)	6b + 6c	33	71	36	47	59	38	25	(100)*	50
VLa, Vk, Va7	4 + 6a + 6b	59	41	44	27	38	22	28	58	24

* only two isolates

Table 4 Effect of fungicide on ang% mildew* on leaf 3 at GS 73 and on yield of *cvs.* Felicie and Riviera with and without a single spray of tebuconazole fungicide in 1998

Cultivar		With fungicide		Without fungicide
Felicie	% mildew on leaf 3 at GS 73	7.24 (1.8)		13.62 (5.5)
Riviera		1.25 (0.13)		4.27 (0.55)
S.E. (50 d.f.)			1.26	
Felicie	Yield (t/ha at 15%)	4.85		4.54
Riviera		4.82		4.47
S.E. (50 d.f.)			0.087	

*actual %s in brackets

REFERENCES

Mercer, P.C. (1998). Mildew of barley in Northern Ireland. *UK Cereal Pathogen Virulence Survey 1997 Annual Report,* pp 52-55.

Slater, S.E. and Clarkson, J.D.S. (1999). Mildew of barley. *UK Cereal Pathogen Virulence Survey 1998 Annual Report,* pp 45-54.

YELLOW RUST OF BARLEY

G. J. HILTON and W. C. HUTTON

National Institute of Agricultural Botany, Cambridge

There were a number of unconfirmed incidences of yellow rust in winter barley, early in the season. However, no yellow rust was present on the samples sent to NIAB.

It is worth noting that there is still a potential for a yellow rust epidemic in winter barley. This is due to the two extremely susceptible varieties Regina and Melanie (both with resistance rating = 2), occupying around 25 % of the winter barley growing area in the 1998/99 season*.

*Based on areas entered for certified seed production, for the 1998 harvest, in the UK (*UK Recommended Lists of Cereals, 1999*).

BROWN RUST OF BARLEY

E.R.L. JONES

Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion SY23 3EB, U.K.

Seedling tests with the 1998 isolates identified virulences, in various combinations, to all the specific resistances carried by the differential cultivars with the exception of Cebada Capa (BRR-7). Some of these differential cultivars expressed resistance in glasshouse adult plant tests to isolates identified as carrying the corresponding virulences in seedling tests. A number of the current NIAB recommended winter barleys were resistant as adult plants to one or more of the isolates tested. Likewise, several of the currently recommended spring barleys were resistant at later growth stages to one or more of the isolates against which they were tested whilst some expressed overall resistance.

GLASSHOUSE SEEDLING TESTS WITH 1998 ISOLATES

Forty-eight of the 73 samples of barley brown rust received in 1998 were collected from a wide range of winter barley cultivars. Of these, 28 were from two trial sites (Harper Adams, one of the West Midlands sites, and Cockle Park, Northumberland). The remainder were from spring barley cultivars, 14 of which came from a trial site at Headley Hall, Yorkshire. The geographic origins of the samples are given in Table 1.

Table 1 Geographical origin of 1998 barley brown rust samples

Location (MAFF region)	Number of samples
North	24
Yorkshire and Humberside	20
West Midlands	16
South west	5
South east	3
East Midlands	2
East Anglia	2
Wales	1

Isolates of *Puccinia hordei* Otth. were cultured from 27 of the samples, these being selected on the basis of their geographic and cultivar origins, and tested on a set of ten 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	1
Peruvian	2	Pa_2	2
Ribari	3	Pa_3	3
Gold	4	Pa_4	4
Quinn	5	$Pa_2 + Pa_5$	5
Bolivia	6	$Pa_2 + Pa_6$	6
Cebada Capa	7	Pa_7	7
Egypt 4	8	Pa_8	8
Hordeum 2596	9	Pa_9	9
Triumph	10	Pa_{10}	10

Results

The virulence combinations (races) identified and their octal designations are given in Table 3.

Table 3 Races identified from 1998 isolates

Number of isolates	Octal designation	BBV factors
12	273	1,2,4,5,6,8
3	277	1,2,3,4,5,6,8
2	1273	1,2,4,5,6,8,10
1	1257	1,2,3,4,6,8,10
7	1673	1,2,4,5,6,8,9,10
2	1677	1,2,3,4,5,6,8,9,10

All the virulence combinations have been identified previously. One, race octal 1677, carries virulence to all of the differential cultivars with the exception of Cebada Capa (BBR-7), virulence to which has not been identified in the UK pathogen population.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF BROWN RUST

Adult plant tests

Twenty-four spring and 26 winter barleys were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included cultivars on the NIAB Recommended Lists of winter and spring barleys as well as the standard set of seedling differential cultivars (Table 2). Two replicates of each cultivar were inoculated with one each of the following isolates:

Isolate	Origin
BRS-98-2 (BBV-1,2,4,5,6,8)	cv. Jewel, Northumberland
BRS-97-2 (BBV-1,2,3,4,6,8,9,10)	cv. Muscat, Northumberland
BRS-97-27 (BBV-1,2,4,6,8,9,10)	cv. Fighter, Lincolnshire

The plants were inoculated by spraying with a spore suspension. They were placed in dew chambers for 16 h at 15°C post-inoculation and then incubated in the glasshouse at approximately 15°C for 14 days. Assessments were made of infection type on the flag leaf. These were classified on the standard 0-4 scale as resistant (R = 0-2) or susceptible S = 3-4).

Seedling tests

Seedlings of the cultivars, grown in a spore-proofed glasshouse to the second leaf stage, were inoculated with the same isolates under the same conditions as the adult plants. Seedling x isolate interactions were assessed on the first leaf and classified on the same 0-4 scale as the adult plants.

Results

Winter barleys

These are given in Table 4. Cultivars were classified into groups on the basis of similarities in the pattern of their adult plant responses to the isolates.

Group 1: Cultivars susceptible.

Group 2: The cultivars were susceptible as adult plants to isolate BRS-98-2 only. This isolate, which is less widely virulent than the other two in these tests, is the only one to carry virulence factor BBV-5, suggesting that the resistance of these cultivars is conferred by BBR-5. Tests in 1997 with different isolates, however, showed several of these cultivars to be resistant to two isolates carrying BBV-5 but susceptible to a third. The reasons for this inconsistency, and its biological significance, are unclear.

Group 3: Cultivars within this group, like those in Group 2, are susceptible to isolate BRS-98-2 but differ from them in also being susceptible to BRS-98-27. They were resistant to isolate BRS-97-2 which carries virulences in addition to those carried by the other two isolates. All winter barley cultivars were seedling susceptible except for cvs Rifle and Puffin which expressed an intermediate response to two of the isolates.

Spring barleys

The responses of the spring barleys are given in Table 5 where cultivars are classified into groups on the basis of the adult plant x isolate interactions.

Group 1: Cultivars susceptible.

Group 2: Cultivar Prisma was resistant to isolate BRS-98-2 (BBV-1,2,4,5,6,8) but susceptible to the other two isolates, both of which carry virulence factors BBV-9 and BBV-10. Previous years' tests suggest that cv. Prisma carries resistance factor BBR-10.

Group 3: Resistance conferred by these cultivars was overcome only by isolate BRS-98-2 at the adult plant stage, suggesting that they carry resistance factor BBR-5 in common with the differential cultivar Quinn. As with some of the winter barley cultivars (Group 2, Table 4), which were also susceptible to this isolate only, previous years' tests have shown them to be resistant to other isolates carrying BBV-5. Of the differential cultivars the overall resistance of cv. Quinn (BBR-5) to races lacking the corresponding virulence was confirmed. Cultivars Sudan (BBR-1) and Bolivia (BBR-6) were resistant as adult plants to isolates BRS-97-2 and BRS-97-47, both of which were identified as carrying virulence factors BBV-1 and BBV-6 in seedling tests.

Group 4: The adult plant resistances of cvs Optic and Century effective against isolate BRS-97-2, which was identified in seedling tests as being the most widely virulent of the isolates used in these tests, were overcome by the other isolates. The differential cv. Egypt 4 (BBR-8) also expressed adult plant resistance to isolate BRS-97-2.

Group 5: The resistances carried by these cultivars were effective at the later growth stages to the three isolates but were overcome in seedling tests by isolates BRS-97-2 and BRS-97-27. The differential cv. Peruvian (BBR-2) also expressed resistance as an adult plant but was susceptible as a seedling to all the isolates. Overall resistance conferred by Cebada Capa (BBR-7) was effective.

Group 6: The differential cv. Estate (BBR-3) was susceptible to isolate BRS-97-2, which was the only one included in these tests identified as carrying the corresponding virulence factor (BBV-3).

Table 4 Adult plant and seedling ( ) *reactions of winter barley cultivars to specific isolates of *Puccinia hordei* under glasshouse conditions

Isolate / Cultivar [NIAB rating]		Group	BRS-98-2 (BBV-1,2,4,5,6,8) Race octal 273	BRS-97-2 (BBV-1,2,3,4,6,8,9,10) Race octal 1657	BRS-97-27 (BBV-1,2,4,6,8,9,10) Race octal 1653
Angora		1	S (S)	S (S)	S (S)
Manitou	[4]		S (S)	S (S)	S (S)
Melanie	[3]		S (S)	S (S)	S (S)
Fighter			S (S)	S (S)	S (S)
Vertige	[5]		S (S)	S (S)	S (S)
Pastoral	[5]		S (S)	S (S)	S (S)
Regina	[6]		S (S)	S (S)	S (S)
Fanfare	[7]		S (S)	S (S)	S (S)
Halcyon	[6]		S (S)	S (S)	S (S)
Muscat	[6]		S (S)	S (S)	S (S)
Linnet			S (S)	S (S)	S (S)
Angela	[7]		S (S)	S (S)	S (S)
Gaelic	[2]	2	S (S)	R (S)	R (S)
Intro	[7]		S (S)	R (S)	R (S)
Flute			S (S)	R (S)	R (S)
Hanna	[5]		S (S)	R (S)	R (S)
Gleam	[6]		S (S)	R (S)	R (S)
Heligan	[7]		S (S)	R (S)	R (S)
Spirit			S (S)	R (S)	R (S)
Pearl	[7]		S (S)	R (S)	MR (S)
Rifle	[8]		S (S)	R (I)	R (I)
Puffin			S (S)	R (I)	R (I)
Baton		3	S (S)	R (S)	MS (S)
Epic	[7]		MS (S)	R (S)	MS (S)
Jewel	[7]		S (S)	R (S)	S (S)
Peridot			S (S)	R (S)	S (S)

*Cultivars assessed on reaction type
0-2 type reaction – resistant (R)
3-4 type reaction – susceptible (S)
When more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant; I = intermediate

Seedlings assessed on 1st leaf. Adult plants assessed on flag leaf
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 5 Adult plant and seedling ( ) *reactions of spring barley cultivars to specific isolates of *Puccinia hordei* under glasshouse conditions

Isolate / Cultivar [NIAB rating] (Resistance factor)		Group	BRS-98-2 (BBV-1,2,4,5,6,8) Race octal 273		BRS-97-2 (BBV-,2,3,4,6,8,9,10) Race octal 1657		BRS-97-27 (BBV-1,2,4,6,8,9,10) Race octal 1653	
Hart	[5]	1	S	(S)	S	(S)	S	(S)
Dandy	[5]		S	(S)	S	(S)	S	(S)
Riviera	[4]		S	(S)	S	(S)	S	(S)
Gold	(BBR-4)		S	(S)	S	(S)	S	(S)
Prisma	[5]	2	R	(R)	S	(S)	S	(S)
Triumph	(BBR-10)		MR	(R)	S	(S)	S	(S)
Hordeum 2596	(BBR-9)		R	(R)	S	(S)	S	(S)
Chariot	[5]	3	S	(S)	R	(S)	R	(S)
Chalice	[6]		MS	(S)	R	(S)	R	(S)
Landlord	[6]		S	(I)	R	(I)	R	(I)
Sudan	(BBR-1)		S	(S)	R	(S)	R	(S)
Bolivia	(BBR-6)		S	(S)	R	(S)	R	(S)
Quinn	(BBR-5)		S	(S)	R	(R)	R	(R)
Optic	[8]	4	S	(R)	R	(S)	S	(S)
Century	[5]		S	(S)	R	(S)	S	(S)
Egypt 4	(BBR-8)		S	(S)	R	(S)	S	(S)
Cooper	[8]	5	R	(R)	R	(S)	R	(S)
Derkado	[7]		R	(R)	R	(S)	MR	(S)
Decanter	[7]		R	(R)	R	(S)	MR	(S)
Delibes [9]			R	(R)	R	(S)	R	(S)
NFC SB495/18			R	(R)	R	(MR)	R	(MS)
Peruvian	(BBR-2)		MR	(S)	R	(S)	R	(S)
Cebada Capa	(BBR-7)		R	(R)	R	(R)	R	(R)
Estate	(BBR-3)	6	R	(R)	S	(S)	R	(R)

*Cultivars assessed on reaction type
0-2 type reaction – resistant (R)
3-4 type reaction – susceptible (S)
When more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant; I = intermediate
Seedlings assessed on 1st leaf. Adult plants assessed on flag leaf
[ ] NIAB rating: 1 = susceptible; 9 = resistant

RHYNCHOSPORIUM OF BARLEY

E. R. L. JONES and A. C. NEWTON[†]

Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion SY23 3EB, U.K.

[†]Scottish Crop Research Institute, Invergowrie, Dundee, U.K.

A range of virulence combinations were identified from the 1998 isolates. Several of the current NIAB recommended winter barleys carry a race-specific resistance (BRR-2). The responses of the winter barley cv. Angela in glasshouse tests suggest it may carry the resistance factor BRR-5. The currently recommended spring barley cultivars were all susceptible, as adult plants and seedlings, to three isolates carrying a range of virulences.

SEEDLING TESTS WITH 1998 ISOLATES

Leaves infected with *Rhynchosporium secalis* were received from 59 winter and 12 spring barley cultivars. The geographic origins of the samples are given in Table 1.

Table 1 Geographic origins of *Rhynchosporium* samples received in 1998

Location (MAFF Region)	Number of samples
North	19
West Midlands	13
South-west	7
East Anglia	7
Scotland	24

Several of the samples were heavily infected with net blotch from which it was not possible to culture isolates of *Rhynchosporium secalis*. Isolates were cultured from 36 of the other samples and tested on a set of differential cultivars. Test cultivars and their resistance factors are given in Table 2.

Table 2 Differential test cultivars for *Rhynchosporium secalis*

BRR Factor	Cultivar	Octal rank
0	Maris Mink	-
1	Armelle	1
2	Astrix	2
3	Athene	3
4	Igri	4
5	La Mesita	5
6	Osiris	6
7	Pirate	7
8	Digger	8

Results

Virulence was identified to all of the specific resistances carried by the test cultivars. The frequencies of individual virulences are given in Table 3 where they are compared to those of previous years.

Table 3 Frequencies of individual virulences, 1989-1998

	BRV-								No. of isolates
	8	7	6	5	4	3	2	1	
1989	-	0.54	0.08	0.23	0.92	0.92	0.62	0.62	15
1990	-	0.54	0.23	0.30	0.76	0.92	0.23	0.23	13
1991	-	0.28	0	0	0.52	0.74	0.22	0.22	50
1992	-	0.50	0.07	0.10	0.86	0.97	0.40	0.40	30
1993	-	0.57	0.07	0.12	0.94	1.00	0.68	0.68	69
1994	-	0.85	0.07	0.15	0.97	0.99	0.88	0.88	67
1995	-	0.26	0.13	0.30	0.65	0.91	0.26	0.26	23
1996	-	0.68	0.18	0.39	0.71	1.00	0.61	0.61	28
1997	0.02	0.37	0.02	0.02	0.96	1.00	0.31	0.31	45
1998	0.03	0.42	0.06	0.22	0.67	1.00	0.72	0.72	36

The higher proportion of isolates cultured from winter barleys (92%) in 1998, many of which have been identified as carrying resistance factor BRR-2 (Table 5) in glasshouse tests, is reflected in an increased frequency (0.72) of the corresponding virulence (BRV-2). Virulence to cv. Osiris (BRR-6) has remained at a low frequency in the pathogen population since its initial identification in 1985. All the cv Osiris-virulent isolates cultured from samples received through the surveys since then have also carried virulence to the differential cv. La Mesita (BRR-5). One of the two isolates identified from the 1998 survey as carrying BRV-6 lacked virulence to cv. La Mesita. Virulence to cv. Digger (BRR-8) was found in one isolate, RS-98-22, cultured from a leaf sample of winter barley, cv. Pearl.

The virulences identified occurred in various combinations in the different isolates (Table 4). The virulence combinations gave a range from a single virulence factor in one isolate to others comprising up to six virulence factors.

Table 4 Virulence factor combinations identified from the 1998 isolates

No. of isolates	Differential cultivars in linear order								Race octal
	Digger	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
1	0	0	0	0	0	1	0	0	4
2	0	0	0	0	1	1	0	0	14
1	0	1	0	0	1	1	0	0	114
1	1	1	0	0	1	1	0	0	314
2	0	0	1	1	1	1	0	0	74
2	0	0	0	1	0	1	0	0	24
1	0	0	0	1	1	1	0	0	34
12	0	0	0	0	1	1	1	1	17
1	0	0	0	1	1	1	1	1	37
11	0	1	0	0	1	1	1	1	117
1	0	1	0	1	1	1	1	1	137
1	0	1	1	0	1	1	1	1	157

1 = susceptible   0 = resistant

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF *RHYNCHOSPORIUM*

Adult plant tests

Winter and spring barleys were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included cultivars on the NIAB Recommended List of winter and spring barleys as well as the standard set of differential cultivars used in seedling tests. Two replicates of each cultivar were inoculated with one of each of the following isolates.

Isolate	†BRV-	Origin
RS-98-32	3,4,5,6	cv. Pipkin, Dorset
RS-98-22	3,4,7,8	cv. Pearl, Northumberland
RS-98-1	1,2,3,4	cv. Regina, Warwickshire

† identified in seedling tests

Plants were inoculated using methods described previously (Jones and Clifford, 1996) and assessed on a 0-9 scale (0-4: resistant; 5-9: susceptible).

Seedling tests

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

Results

Winter barleys: These are given in Table 5. Cultivars are grouped within the table on the basis of similarities in the patterns of their adult plants responses to the isolates.

Group 1: Cultivars were susceptible although quantitative differences in levels of infection were evident between them.

Group 2: These cultivars were resistant to two of the isolates but susceptible to isolate RS-98-1 (BRV-1,2,3,4) which is the only one in these tests to carry virulence factors BRV-1 and BRV-2. The newly introduced winter barleys CPBT B 23, Vanessa and 12431 VH 1, which were tested as seedlings only, showed a similar pattern of responses to the isolates.

Group 3: The specific resistance BRR-5 carried by cv. Pipkin has previously been seen to be ineffective at later growth stages to isolates not carrying the corresponding virulence (Jones and Clifford, 1982). In these tests cv. Pipkin was susceptible to the three isolates against which it was tested, but its resistance was effective in seedling tests to the two isolates lacking the corresponding virulence, BRV-5. Cultivar Angela gave a similar pattern of responses to the isolates.

Group 4: The resistance of cv. Manitou which has been effective against several isolates, particularly at later growth stages in previous years' glasshouse tests, was overcome albeit at generally low levels, by two of the isolates.

Group 5: Seedling tests showed cv. Pirate (BRR-7) to be susceptible to isolate RS-98-22 which has previously been identified as carrying the corresponding virulence.

Spring barleys: The levels of infection displayed by these are given in Table 6 where cultivars are again grouped on the basis of similarities in the patterns of their responses to the isolates.

Group 1: All the currently NIAB recommended spring barleys were susceptible to the three isolates, although quantitative differences in levels of infection were expressed, particularly at later growth stages.

Group 2: The resistance of cv. Armelle (BRR-1) was effective against isolates RS-98-32 and RS-98-22 which do not carry the corresponding virulence factor (BRV-1).

Group 3: Cultivar La Mesita, which like the winter barley cv. Pipkin carries resistance factor BRR-5, was susceptible as an adult plant to isolates not identified in seedling tests as carrying the corresponding virulence factor. In seedling tests it was susceptible only to isolate RS-98-32, which carries virulence factor BRV-5.

Group 4: Isolate RS-98-32 has been identified in previous seedling tests as carrying virulence to cv. Osiris (BRR-6). This virulence was confirmed in these glasshouse seedling tests but the isolate failed to induce a susceptible response on cv. Osiris in adult plant tests.

Group 5: Cultivar Digger was susceptible to isolate RS-98-22 although it expressed lower levels of infection as an adult plant than as a seedling.

ADULT PLANT FIELD NURSERIES

A nursery comprising the 1997 NIAB Recommended List of spring barleys, together with cultivars carrying known specific resistances, was grown at SCRI. The susceptible cultivars within the nursery became infected naturally.

Results

Assessment of percentage infection levels were made and results are given in Table 7. A range of quantitative responses was displayed with the susceptible cultivars showing high levels of infection. The naturally-occurring pathotypes which invaded the nursery failed to overcome the resistances carried by the standard differential cultivars.

REFERENCES

Jones, E.R.L. & Clifford, B.C. (1996). *Rhynchosporium* of barley. *UK Cereal Pathogen Virulence Survey 1995 Annual Report*, pp.56-60.

Jones, E.R.L. & Clifford, B.C. (1982). *Rhynchosporium* of barley. *UK Cereal Pathogen Virulence Survey 1981 Annual Report*, pp.61-64.

e 5 *Reactions of winter barley cultivars, adult plants and seedlings ( ), to specific isolates of *Rhynchosporium secalis* in glasshouse tests

ltivar/isolate IAB rating] esistance factor)	Group	RS-98-32 (Race octal 74) BRV-3,4,5,6		RS-98-22 (Race octal 314) BRV-3,4,7,8		RS-98-1 (Race octal 17) BRV-1,2,3,4	
	1						
Maris Otter		8	(9)	9	(9)	8	(8)
Gaelic		9	(5)	7	(9)	8	(7)
Vertige [5]		8	(8)	8	(7)	8	(6)
Fighter		8	(5)	6	(8)	6	(8)
Rifle [5]		8	(5)	6	(5)	7	(6)
Flute [8]		8	(9)	6	(6)	8	(6)
Pastoral [7]		8	(8)	6	(8)	9	(8)
Puffin		7	(5)	6	(7)	9	(5)
Fanfare [8]		8	(6)	7	(8)	6	(6)
Muscat [8]		8	(5)	7	(5)	6	(6)
Jewel [8]		6	(9)	8	(8)	8	(6)
Peridot		5	(5)	5	(5)	8	(5)
Epic [5]		5	(6)	5	(8)	8	(7)
Pearl [8]		-	(9)	-	(8)	-	(8)
Antonia [8]		-	(5)	-	(8)	-	(5)
Athene (BRR-3)		8	(8)	-	(8)	-	(9)
Igri (BRR-4)		-	(8)	-	(5)	-	(9)
	2						
Intro [5]		0	(0)	0	(0)	9	(8)
Halcyon [5]		0	(0)	0	(0)	8	(7)
Regina [7]		0	(0)	0	(0)	8	(6)
Angora		0	(0)	0	(0)	7	(7)
Melanie [8]		0	(0)	0	(0)	8	(7)
Baton		1	(0)	0	(0)	9	(6)
Gleam [7]		0	(0)	0	(0)	-	(6)
Spirit		1	(0)	0	(0)	7	(5)
Linnet		3	(9)	0	(2)	8	(6)
Hanna [8]		3	(5)	2	(4)	8	(6)
Astrix (BRR-2)		0	(0)	-	(0)	8	(8)
CPBT B 23		0	(0)	-	(0)	-	(6)
Vanessa [4]		-	(0)	-	(0)	-	(8)
12431 VH 1		-	(0)	-	(0)	-	(6)
Pipkin [3]	3	8	(8)	7	(1)	7	(1)
Angela [8]		5	(5)	5	(0)	8	(0)
Manitou [8]	4	6	(3)	5	(5)	0	(0)
Pirate (BRR-7)	5	1	(0)	-	(5)	-	(3)

* Assessments of leaf area infected on a 0-9 scale (mean of 2 plants)
Resistant: 0-4; Susceptible: 5-9
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Group 2: The resistance of cv. Armelle (BRR-1) was effective against isolates RS-98-32 and RS-98-22 which do not carry the corresponding virulence factor (BRV-1).

Group 3: Cultivar La Mesita, which like the winter barley cv. Pipkin carries resistance factor BRR-5, was susceptible as an adult plant to isolates not identified in seedling tests as carrying the corresponding virulence factor. In seedling tests it was susceptible only to isolate RS-98-32, which carries virulence factor BRV-5.

Group 4: Isolate RS-98-32 has been identified in previous seedling tests as carrying virulence to cv. Osiris (BRR-6). This virulence was confirmed in these glasshouse seedling tests but the isolate failed to induce a susceptible response on cv. Osiris in adult plant tests.

Group 5: Cultivar Digger was susceptible to isolate RS-98-22 although it expressed lower levels of infection as an adult plant than as a seedling.

ADULT PLANT FIELD NURSERIES

A nursery comprising the 1997 NIAB Recommended List of spring barleys, together with cultivars carrying known specific resistances, was grown at SCRI. The susceptible cultivars within the nursery became infected naturally.

Results

Assessment of percentage infection levels were made and results are given in Table 7. A range of quantitative responses was displayed with the susceptible cultivars showing high levels of infection. The naturally-occurring pathotypes which invaded the nursery failed to overcome the resistances carried by the standard differential cultivars.

REFERENCES

Jones, E.R.L. & Clifford, B.C. (1996). *Rhynchosporium* of barley. *UK Cereal Pathogen Virulence Survey 1995 Annual Report*, pp.56-60.

Jones, E.R.L. & Clifford, B.C. (1982). *Rhynchosporium* of barley. *UK Cereal Pathogen Virulence Survey 1981 Annual Report*, pp.61-64.

Table 5 *Reactions of winter barley cultivars, adult plants and seedlings ( ), to specific isolates of *Rhynchosporium secalis* in glasshouse tests

Cultivar/isolate [NIAB rating] (Resistance factor)	Group	RS-98-32 (Race octal 74) BRV-3,4,5,6		RS-98-22 (Race octal 314) BRV-3,4,7,8		RS-98-1 (Race octal 17) BRV-1,2,3,4	
Maris Otter	1	8	(9)	9	(9)	8	(8)
Gaelic		9	(5)	7	(9)	8	(7)
Vertige [5]		8	(8)	8	(7)	8	(6)
Fighter		8	(5)	6	(8)	6	(8)
Rifle [5]		8	(5)	6	(5)	7	(6)
Flute [8]		8	(9)	6	(6)	8	(6)
Pastoral [7]		8	(8)	6	(8)	9	(8)
Puffin		7	(5)	6	(7)	9	(5)
Fanfare [8]		8	(6)	7	(8)	6	(6)
Muscat [8]		8	(5)	7	(5)	6	(6)
Jewel [8]		6	(9)	8	(8)	8	(6)
Peridot		5	(5)	5	(5)	8	(5)
Epic [5]		5	(6)	5	(8)	8	(7)
Pearl [8]		-	(9)	-	(8)	-	(8)
Antonia [8]		-	(5)	-	(8)	-	(5)
Athene (BRR-3)		8	(8)	-	(8)	-	(9)
Igri (BRR-4)		-	(8)	-	(5)	-	(9)
Intro [5]	2	0	(0)	0	(0)	9	(8)
Halcyon [5]		0	(0)	0	(0)	8	(7)
Regina [7]		0	(0)	0	(0)	8	(6)
Angora		0	(0)	0	(0)	7	(7)
Melanie [8]		0	(0)	0	(0)	8	(7)
Baton		1	(0)	0	(0)	9	(6)
Gleam [7]		0	(0)	0	(0)	-	(6)
Spirit		1	(0)	0	(0)	7	(5)
Linnet		3	(9)	0	(2)	8	(6)
Hanna [8]		3	(5)	2	(4)	8	(6)
Astrix (BRR-2)		0	(0)	-	(0)	8	(8)
CPBT B 23		0	(0)	-	(0)	-	(6)
Vanessa [4]		-	(0)	-	(0)	-	(8)
12431 VH 1		-	(0)	-	(0)	-	(6)
Pipkin [3]	3	8	(8)	7	(1)	7	(1)
Angela [8]		5	(5)	5	(0)	8	(0)
Manitou [8]	4	6	(3)	5	(5)	0	(0)
Pirate (BRR-7)	5	1	(0)	-	(5)	-	(3)

* Assessments of leaf area infected on a 0-9 scale (mean of 2 plants)
Resistant: 0-4; Susceptible: 5-9
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 6 *Reactions of spring barley cultivars, adult plants and seedlings ( ), to specific isolates of *Rhynchosporium secalis* in glasshouse tests

Cultivar/Isolate [NIAB rating] (Resistance factor)		Group	RS-98-32 BRV-3,4,5,6		RS-98-22 BRV-3,4,7,8		RS-98-1 BRV-1,2,3,4	
Optic	[4]	1	9	(8)	8	(8)	9	(9)
Prisma	[6]		9	(9)	8	(9)	9	(9)
NFC SB495/18			9	(8)	7	(8)	8	(8)
Century	[8]		8	(9)	9	(9)	8	(8)
Chariot	[3]		7	(9)	9	(8)	8	(9)
Derkado	[3]		8	(9)	8	(9)	8	(9)
Delibes	[7]		8	(9)	9	(9)	8	(9)
Chalice	[5]		8	(9)	7	(9)	6	(6)
Riviera	[6]		8	(9)	7	(9)	8	(8)
Cooper	[6]		8	(8)	7	(9)	7	(8)
Dandy	[8]		7	(9)	6	(8)	5	(8)
Hart	[6]		6	(9)	9	(9)	9	(9)
Landlord			6	(5)	6	(8)	5	(8)
		[6	5	(9)	5	(9)	5	(9)
	]							
Decanter			0	(0)	0	(0)	8	(8)
Armelle	(BRR-1)	2	8	(8)	7	(0)	7	(1)
La Mesita	(BRR-5)	3	2	(8)	0	(1)	2	(1)
Osiris	(BRR-6)	4	0	(2)	5	(8)	1	(1)
Digger	(BRR-8)	5						

* Assessments of leaf area infected on a 0-9 scale (mean of 2 plants)
Resistant: 0-4; Susceptible: 5-9
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 7 Infection of spring barley cultivars in the SCRI *Rhynchosporium* nursery in 1998

Cultivar	[NIAB rating]	Resistance factor	Mean % infection
Derkado	[3]		49.0
Optic	[4]		42.3
Chariot	[3]		34.1
Decanter	[5]		32.8
NFCSB495/18			30.5
Landlord	[6]		29.3
Triumph			28.9
Prisma	[6]		27.6
Chalice	[5]		24.7
Riviera	[6]		24.6
Cooper	[6]		24
Hart	[6]		22.3
Delibes	[7]		15.3
Dandy	[8]		8.9
La Mesita		BRR-5	7.3
Century	[8]		5.3
Digger		BRR-8	2.3
Osiris		BRR-6	0.4
Igri		BRR-4	0.2
Armelle		BRR-1	0
Astrix		BRR-2	0
Athene		BRR-3	0
Pirate		BRR-7	0
Livet			0
SED			6.3

[ ] NIAB rating: 1 = susceptible; 9 = resistant

NET BLOTCH OF BARLEY

E.R.L. JONES

Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion SY23 3EB, U.K.

A high proportion (55%) of the 1998 samples were received from cv. Regina which has previously shown good levels of resistance in adult plant glasshouse tests. It was susceptible in similar tests to a mixture of isolates cultured from the 1998 leaf samples. Spring and winter barleys currently on the NIAB Recommended List displayed a range of responses.

Twenty samples of net blotch were received from winter barley cultivars in 1998. Eleven of these came from cv. Regina which has expressed good levels of adult plant resistance to the isolates against which it has been tested in the glasshouse in 1996 and 1997. The majority of the cv. Regina samples were collected from crops recorded as having only low levels of infection (<5%) but two samples from Lincolnshire were more heavily infected (14% and 17% flag leaf area infected). The geographic origins of the leaf samples are given in Table 1.

Table 1 Geographic origins of 1998 net blotch samples

Location (MAFF Region)	Number of samples
West Midlands	8
East Midlands	4
East Anglia	3
South East	3
South West	1
Scotland	1

The 1998 samples were not tested individually on the standard set of seedling differential cultivars, because as agreed at the 1998 meeting of the UK-CPVS such tests were currently of little value.

ADULT PLANT TESTS

Winter and spring barley cultivars were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included those cultivars currently on the NIAB Recommended Lists of winter and spring barleys as well as the standard set of seedling differential cultivars. Two replicates of each cultivar were inoculated with a mixture of isolates obtained from the following samples:

Isolate	Origin
BNS-98-1	cv. Pipkin, Essex
BNS-98-2	cv. Muscat, Aberdeenshire
BNS-98-15	cv. Pearl, Shropshire
BNS-98-17	cv. Regina, Lincoln

Following inoculation the plants were placed in dew chambers in the dark at 15°C for 24 h post-inoculation and then incubated in the glasshouse at approximately 15°C for 12 days. Assessments were made of infection levels on the flag leaves and cultivars were classified on a 0-9 scale as being resistant (0-4) or susceptible (5-9).

Seedling tests

Seedlings of the cultivars grown to the second leaf stage were inoculated with the same mixture of isolates under identical conditions to the adult plants. Seedling reactions were assessed on the second leaf and classified on a 0-4 scale (Clifford and Jones, 1981) as resistant (0-2) or susceptible (3-4).

Results

Disease symptoms on the adult plants were mainly of a striping or blotching type whereas those on the seedlings were generally of a netting or spotting type.

Winter barleys: The winter barley cultivars, including the differential cultivars, were seedling susceptible (Table 2). The majority were also susceptible as adult plants with only cvs Gaelic, Pastoral, Pearl and Vertige being classified as resistant. Cultivar Regina, designated a rating of 2 in similar tests with different isolates in 1996 and 1997, was susceptible to the mixture of 1998 isolates. This mixture included an isolate cultured from BNS-98-17 which was sampled from a crop of cv. Regina assessed as having 14% of its flag leaf area infected. The increased susceptibility of cv. Regina in these glasshouse tests, together with the high proportion of samples received from crops of this cultivar in 1998, indicates increased virulence in the pathogen population to this winter barley.

Spring barleys: The spring barley cultivars displayed a range of adult plant responses to the mixture of isolates (Table 3). Cultivars generally showed levels of disease similar to those they had expressed in 1997 tests to a different isolate. The increased susceptibility of cvs Optic, Landlord and Dandy seen in 1997 tests was not confirmed with infection levels on these cultivars reverting to near or at their 1996 values. Seedling tests identified virulence to the differential cvs C.I. 1243, C.I. 4979 and Proctor.

REFERENCE

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

Table 2 Adult plant and seedling reactions of winter barley cultivars to a mixture of net blotch isolates under glasshouse conditions

Cultivar [NIAB Rating]		Differential code number	*Adult plant reaction	†Seedling reaction
Puffin			8	4
Angora			8	3
Manitou	[4]		7	4
Melanie	[5]		8	3
Angela	[6]		7	3
Heligan[8]			7	4
Linnet			7	3
Muscat	[7]		7	3
Halcyon	[8]		7	3
Epic	[8]		7	4
Fighter			6	4
Gleam	[4]		6	4
Hanna	[7]		6	3
Peridot			6	3
Fanfare	[7]		6	3
Rifle	[7]		6	3
Regina	[8]		5	4
Flute	[8]		5	4
Jewel	[6]		5	3
Spirit			5	4
Baton			5	3
Intro	[7]		4	3
Gaelic			3	4
Pastoral	[7]		3	4
Pearl	[5]		2	4
Vertige	[8]		2	3
Code 65		10	5	3
C.I.9518		11	8	4
Tenn.61-19		12	8	4

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

† = seedlings assessed on reaction type on a 0-4 scale
Resistant: 0-2, Susceptible: 3-4
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 3 Adult plant and seedling reactions of spring barley cultivars to a mixture of net blotch isolates under glasshouse conditions

Cultivar	Differential Code number	*Adult plant reaction	†Seedling reaction
Prisma		8	4
Chalice		8	4
Century		8	4
NFC SB95/18		7	4
Riviera		6	4
Derkado		5	4
Delibes		5	3
Cooper		5	3
Optic		4	4
Landlord		3	3
Hart		3	2
Chariot		3	3
Dandy		3	3
C.I.5401	1	1	2
C.I.6311	2	0	2
C.I.9820	3	2	1
C.I.739	4	2	2
C.I.1243	5	4	3
C.I.4795	6	3	2
C.I.4502	7	2	2
C.I.4979	8	3	3
Proctor	9	7	4
C.I.9214	13	4	2

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

† seedling assessed on reaction type on a 0-4 scale
Resistant: 0-2, Susceptible: 3-4

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

M.J. ADAMS and C.R. COLLIER

IACR-Rothamsted, Harpenden, Herts, AL5 2JQ

Only 39 infected samples were received in 1998, 12 of which contained barley mild mosaic virus (BaMMV) alone, 21 had barley yellow mosaic virus (BaYMV) alone and 6 contained both viruses. This is the smallest number of samples since the survey began in 1987 and provided insufficient data to analyse cultivar responses. No new outbreaks of resistance-breaking BaYMV were reported.

INTRODUCTION

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

METHODS

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

RESULTS AND DISCUSSION

Only 39 positive samples were received in 1998 of which most (27 samples; 69%) contained BaYMV and 18 (46%) had BaYMV (Table 1). This is the smallest number of samples since the survey began in 1987 (Fig. 1) and provided insufficient data to make any sensible analysis of cultivar differences. A combination of a dry autumn and mild winter may be partially responsible. No new outbreaks of resistance-breaking BaYMV were reported.

Table 1 Mosaic virus samples from 1998, classified by cultivar

Cultivar	BaMMV alone	BaYMV alone	Both viruses	Total samples
Angora	0	1	0	1
Fighter	3	4	0	7
Hanna	0	2	0	2
Intro	0	3	0	3
Feeding	3	10	0	13
Fanfare	0	1	2	3
Halcyon	1	0	1	2
Melanie	0	1	0	1
Pipkin	1	0	0	1
Regina	0	4	0	4
Malting	2	6	3	11
Unknown	7	5	3	15
TOTAL	12	21	6	39

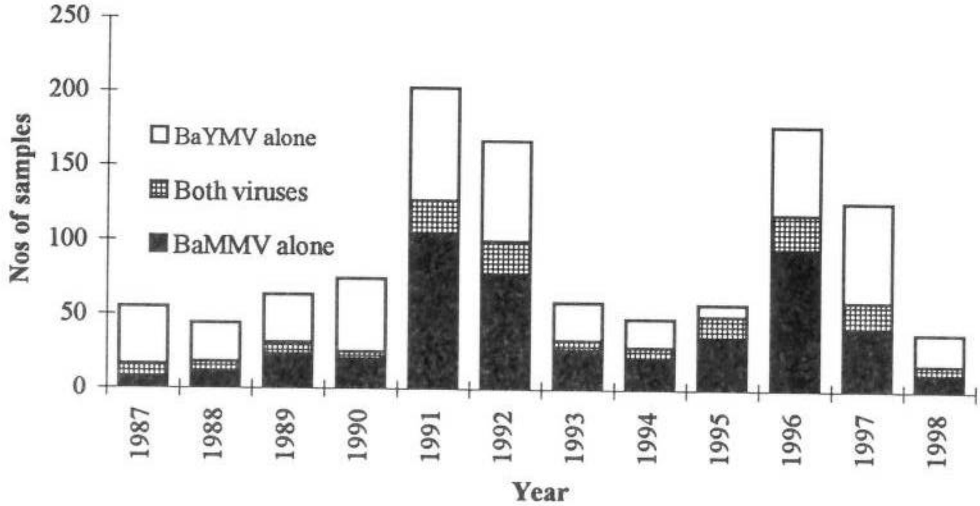

Fig. 1 Numbers of samples of the barley mosaic viruses received during each year of the survey

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

Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion SY23 3EB, U.K.

Race 5 (OMV 1,2,3) was predominant, being identified in 93% of the isolates. The remaining two isolates combined these virulence factors with OMV-4 (Race 7). The current NIAB recommended winter and spring oat cultivars were susceptible as adult plants to the isolates against which they were tested in the glasshouse. A range of quantitative responses was expressed in these tests.

SEEDLING TESTS WITH 1998 ISOLATES

Thirty samples of oat mildew were received in 1998 from a range of spring oat cultivars. Twenty-four came from two trial sites: Headley Hall, Leeds and Cockle Park, Northumberland (Table 1).

Table 1 Geographic origins of oat mildew samples received in 1998

Location (MAFF Region)	Number of samples
North	12
Yorkshire and Humberside	12
Scotland	5
South West	1

Isolates of *Erysiphe graminis avenae* were cultured from 27 of the infected leaf samples and tested on a set of differential cultivars (Table 2).

Table 2 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

Race 5 (OMV-1,2,3) was predominant, being found in 25 of the isolates. The only other virulence combination identified was OMV-1,2,3,4 (Race 7) which was carried by two isolates: OMS-98-17 cultured from a sample of cv. Dula, Fife and OMS-98-24 cultured from infected leaves of cv. Zvolen, one of 12 samples received from Cockle Park, Northumberland. Race 7, which combines virulence to all the differential cultivars, was not identified in 1997 and has, with the exception of 1991, remained at a generally low frequency in the pathogen population since it was first identified in 1980.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF OAT MILDEW

Adult plant tests

Winter and spring oat cultivars were grown in a spore-proofed glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with one or other of the following isolates:

Isolate	Origin	Race
OMS-98-19	cv. Valiant, Cockle Park, Northumberland	5 (OMV-1,2,3)
OMS-98-24	cv. Zvolen, Cockle Park, Northumberland	7 (OMV-1,2,3,4)

Assessments were made of the percentage area of the flag leaf infected and of infection type classified on the standard 0-4 scale as resistant (R = 0-2) or susceptible (S = 3-4).

Seedling tests

Seedlings of the cultivars, grown in a spore-proofed glasshouse, were inoculated with the same isolates under the same conditions as the adult plants. Seedling x isolate interactions were assessed on the 1st leaf and classified on the same 0-4 scale as the adult plants.

Results

Adult plant and seedling test results are given in Table 3.

The spring and winter oat cultivars were susceptible at both growth stages. A range of quantitative responses were expressed by the cultivars at the adult plant stage with cultivar rankings between isolates showing a similar pattern. The winter oats cvs Jalna, Lexicon, Solva, Gerald and Emperor were resistant to an isolate carrying virulence factors OMV-1,2,3 in 1997 adult plant tests but were susceptible in 1998 to isolate OMS-98-19 which was identified as carrying the same combination of virulences.

Table 3 †Percent infection of adult plant flag leaves and adult plant and seedling ( ) *reactions of winter and spring oat cultivars to specific isolates of *Erysiphe graminis avenae* under glasshouse conditions

Cultivar/Isolate [NIAB rating]		OMS-98-19 Race 5 (OMV-1,2,3)			OMS-98-24 Race 7 (OMV-1,2,3,4)		
		% Infection	Reaction type		% Infection	Reaction type	
			Adult	Seedling		Adult	Seedling
Spring oats							
Dula	[3]	70	S	(S)	70	S	(S)
Valiant	[4]	70	S	(S)	65	S	(S)
Sailor	[7]	70	S	(S)	65	S	(S)
Aberglen	[7]	60	S	(S)	50	S	(S)
Drummer	[6]	60	S	(S)	50	S	(S)
Banquo	[7]	60	S	(S)	50	S	(S)
Amigo	[6]	55	S	(S)	60	S	(S)
Bullion	[7]	40	S	(S)	43	S	(S)
Melys	[7]	18	S	(S)	20	S	(S)
Winter oats							
Grafton	[4]	60	S	(S)	55	S	(S)
Harpoon	[4]	40	S	(S)	50	S	(S)
Aintree	[4]	38	S	(S)	50	S	(S)
Viscount	[3]	35	S	(S)	20	S	(S)
Jalna	[6]	28	S	(S)	20	S	(S)
Gerald	[4]	25	S	(S)	23	S	(S)
Krypton	[7]	23	S	(S)	18	S	(S)
Image	[4]	18	S	(S)	28	S	(S)
Lexicon	[7]	15	S	(S)	8	S	(S)
Solva	·	13	S	(S)	18	S	(S)
Millenium	[5]	10	S	(S)	15	S	(S)
Emperor		6	S	(S)	4	S	(S)

†Percent infection = mean of 2 replicates
*0-2 type reaction - resistant (R)
3-4 type reaction - susceptible (S)
[ ] NIAB rating: 1 = susceptible; 9 = resistant

CROWN RUST OF OATS

E.R.L. JONES

Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion SY23 3EB, U.K.

Seedling tests identified two races, 251 and 275, from the 1998 samples. Adult plant tests under glasshouse conditions identified resistance in cvs Sailor and Millenium to the isolates tested.

GLASSHOUSE SEEDLING TESTS WITH 1998 ISOLATES

Eleven samples of oat crown rust were received in 1998. Isolates of *Puccinia coronata* were cultured from eight of these and tested on the International Set of 10 differential cultivars: Anthony, Victoria, Appler, Bond, Landhafer, Santa Fé, Ukraine, Trispernia, Bondvic and Saia. The geographic and cultivar origins of the samples and the races identified are given in Table 1.

Table 1 Geographic and cultivar origins of crown rust samples received in 1998 with races identified for isolates cultured from them

Cultivar	Location	Race
Aintree	Wales	275
Gerald	Hereford	251
Krypton	Hereford	251
Emperor	Wales	251
Breeding Line	Dorset	251
Gerald	Dorset	251
Millenium	Dorset	-
Bullion	Cornwall	-
Revisor	Cornwall	251
Bullion	Wales	-
Millenium	Wales	251

The commonly occurring race 251, which carries virulence to the differential cvs Appler, Bond and Saia, was found in all but one of the isolates. Isolate CRS-98-1 additionally carries virulence to the differential cv. Ukraine and is designated race 275, previously identified in 1995.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF CROWN RUST

Adult plant tests

Nine spring and twelve winter oat cultivars were grown in a spore-proofed glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with one or other of the following isolates:

Isolate	Origin	Race
CRS-97-2	Unknown, Cambridge	251
CRS-98-1	cv. Aintree, Wales	275

The plants were inoculated by spraying with a spore suspension. They were placed in dew simulation chambers for 16 h at 15°C post-inoculation and then incubated in the glasshouse at approximately 15°C for 16 days.

Assessments were made of the percentage area of the flag leaf infected and of infection type classified on the standard 0-4 scale as resistant (R = 0-2) or susceptible (S = 3-4).

Seedling tests

Seedlings of the cultivars, grown in a spore-proofed glasshouse to the second leaf stage, were inoculated with the sasme isolates under the same conditions as the adult plants. Seedling x isolate interactions were assessed on the 1st leaf and classified on the same 0-4 scale as the adult plants.

Results

These are given in Table 2. The majority of the cultivars, winters and springs, were susceptible as seedlings and adult plants to both isolates although a range of quantitative responses were expressed. The spring oat cv. Sailor and the winter oat cv. Millenium were resistant to the isolates.

Table 2 †Percent infection of adult plant flag leaves and adult plant and seedling ( ) *reactions of winter and spring oat cultivars to specific isolates of *Puccinia coronata* under glasshouse conditions.

Cultivar/Isolate	[NIAB rating]	CRS-97-2 (Race 251)			CRS-98-1 (Race 275)		
Aberglen■	[2]	60	S	(S)	30	S	(S)
Harpoon	[5]	60	S	(S)	33	S	(S)
Krypton	[6]	50	S	(S)	40	S	(S)
Banquo■	[(6)]	50	S	(S)	33	S	(S)
Bullion■	[(3)]	50	S	(S)	28	S	(S)
Emperor		48	S	(S)	38	S	(S)
Dula■	[5]	45	S	(S)	35	S	(S)
Jalna	[5]	45	S	(S)	30	S	(S)
Solva		45	S	(S)	28	S	(S)
Drummer■	[(6)]	40	S	(S)	33	S	(S)
Lexicon	[7]	38	S	(S)	35	S	(S)
Image	[3]	38	S	(S)	35	MS	(S)
Valiant■	[3]	38	S	(S)	35	MS	(S)
Melys■	[6]	38	S	(S)	30	S	(S)
Amigo■	[(4)]	35	S	(S)	40	S	(S)
Aintree	[4]	33	S	(S)	25	S	(S)
Grafton	[(4)]	30	S	(S)	23	S	(S)
Millenium	[(9)]	20	MR	(R)	15	MR	(R)
Sailor■	[(9)]	55	R	(R)	45	R	(R)

■ Spring oat
† Percent infection - mean of 2 replicates
* 0-2 type reaction - resistant (R)
3-4 type reaction - susceptible (S)

When more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response.

MS = mixed susceptible; MR = mixed resistant

[ ] NIAB rating: 1 = susceptible; 9 = resistant; [( )] = limited data

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1999

Variety diversification schemes to reduce the spread of mildew in spring barley and yellow rust in winter wheat have been produced by the UKCPVS Committee since 1975. In 1986, the barley scheme was expanded to include both winter and spring varieties. In 1988, spring wheat varieties were added to the wheat scheme. The schemes which follow update those shown in the 1997 Annual Report.

The scheme for mildew of wheat was suspended in 1990, its usefulness having been severely restricted by the limited range of specific resistances in current varieties and by the increasing complexity of the mildew population. However, the situation is under constant review and the mildew scheme will be reinstated when appropriate. Wheat varieties with good resistance to mildew are available and should be grown whenever possible.

The brown rust of wheat scheme has also been suspended for the present, due to the lack of suitable diversification available in current varieties. This situation will be reviewed each year.

Diversification schemes are used to encourage farmers to grow a number of varieties possessing different specific resistances, either in adjacent fields or, possibly, in the same field as a variety mixture. Disease is unlikely to spread between varieties possessing different specific resistances because spores generated on one variety are largely non-virulent on the other.

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

REFERENCES

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

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

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

VARIETY DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF YELLOW RUST IN WHEAT, 1999

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

Choosing varieties to grow together

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

DG1
*(*)*
Buster
Charger
Claire
Consort
Malacca
Axona (S)
Chablis (S)
Imp (S)
Paragon (S)
Shiraz (S)

DG2
(WYR6,9)
Rialto

DG3
(WYR13)
Riband

DG7
(WYR CV)
Hereward
Shamrock
Spark

DG9
(WYR17)
Abbot
Brigadier
Buchan
Hussar
Reaper
Savannah

DG10
(WYR6,17)
Equinox
Madrigal

DG0
*(**)*
Soissons

(S) = *spring wheat*

	Companion DG						
Chosen DG	**1**	**2**	**3**	**7**	**9**	**10**	**0**
1	+	+	+	+	+	+	+
2	+	Y	y	+	y	y	Y
3	+	y	Y	y	y	y	Y
7	+	+	y	Y	+	+	Y
9	+	y	y	+	Y	y	Y
10	+	y	y	+	y	Y	Y
0	+	Y	Y	Y	Y	Y	Y

* Varieties in DG1 have good resistance to all races and can therefore be used to diversify with varieties in any DG, including others in DG1.

** Varieties in DG0 are susceptible or moderately susceptible to all races and therefore do not contribute to diversification.

VARIETY DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY, 1999

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

Choosing varieties to grow together

1. Select first-choice variety and locate its Diversification Group (DG).
2. Find this DG number under 'Chosen DG' down the left hand side of the table.
3. Read across the table to find the risk of spread of mildew for each companion DG.

DG1
Angela (W)
Pearl (W)
Alexis (S)
Century (S)
Chalice (S)
Chariot (S)
Dandy (S)
Decanter (S)
Derkado (S)
Hart (S)
Landlord (S)
Riviera (S)
Static (S)

DG5
Jewel (W)
Rifle (W)
Flute (W)

DG7
Cooper (S)
Delibes (S)

DG8
Manitou (W)

DG9
Optic (S)

DG10
Epic (W)
Gleam (W)

DG0
Fanfare (W)
Halcyon (W)
Hanna (W)
Heligan (W)
Intro (W)
Melanie (W)
Muscat (W)
Pastoral (W)
Pipkin (W)
Regina (W)
Vertige (W)
Prisma (S)

Companion DG

Chosen DG	1	5	7	8	9	10	0
1	+	+	+	+	+	+	+
5	+	M	M	+	M	M	M
7	+	M	M	M	M	+	M
8	+	+	M	M	M	+	M
9	+	M	M	M	M	+	M
10	+	M	+	+	+	M	M
0	+	M	M	M	M	M	M

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

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

NOTES