UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

Chairman:	Dr R Johnson
Secretary:	Dr R A Bayles NIAB Huntingdon Road Cambridge CB3 0LE UK [Tel: 44 (0)1223 276381]

2001 Annual Report

Editor: J D S Clarkson

Published by

The United Kingdom Cereal Pathogen Virulence Survey Committee

Cambridge, U.K.

April 2002

Price £20-00

Printed by NIAB, Cambridge

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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 variety 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 plant 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:

- NIAB, Cambridge - for mildew and yellow rust of both wheat and barley.
- Institute of Grassland and Environmental Research, Aberystwyth - for brown rust of both wheat and barley, rhynchosporium and net blotch of barley, mildew and crown rust of oats.

Other sampling methods, such as static seedling nurseries, may be employed, *eg* for barley mildew.

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 resistance(s). 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 NIAB 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 variety diversification schemes, modified to meet regional requirements, are published by NIAB and by SAC in Scotland.

The UKCPVS is funded by DEFRA and HGCA.

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. Increasingly, agreed European nomenclature has been adopted, particularly for the mildews and for wheat brown rust.

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.

OCTAL NOTATION

In 1979 the octal system of notation was introduced and applied to races of *Puccinia hordei* identified by the UKCPVS in that year. This followed the proposal of Clifford at the 4th European and Mediterranean Cereal Rust Conference in Interlaken in 1976 to standardise differential host genotypes and adopt the octal/binary system (Gilmour, 1973) for race nomenclature. In 1983 isolates of *Rhynchosporium secalis* were designated race numbers using this system.

Designation of virulence combinations (races) by octal number:

1. Place differential cultivars in fixed linear order with the lowest number on the right and in groups of three.

   9 8 7 6 5 4 3 2 1
   (binary triplet)

   New genotypes can be added to the left either to add to or start a new binary triplet.

2. Assign a binary number to the reaction type shown by each of the differential cultivars.

   R = 0
   S = 1

3. Convert each resulting binary triplet to its unique octal number.

Binary triplet			Octal number	
0	0	0	0	(0+0+0)
0	0	1	1	(0+0+1)
0	1	0	2	(0+2+0)
0	1	1	3	(0+2+1)
1	0	0	4	(4+0+0)
1	0	1	5	(4+0+1)
1	1	0	6	(4+2+0)
1	1	1	7	(4+2+1)

4. Example.

Differential	9	8	7	6	5	4	3	2	1
Reaction	S	R	R	S	R	S	S	S	S
Binary	1	0	0	1	0	1	1	1	1
Octal		4			5			7	

5. Conversely, if the fixed ranking of the differential cultivars is known, a given octal number can be decoded to reveal the description of the virulence/avirulence spectrum of a particular pathogen isolate.

REFERENCE: Gilmour, J. (1973). Octal notation for designating physiologic races of plant pathogen. *Nature* Lond. **242,** 620.

UKCPVS 2001: SUMMARIES of RESULTS

- **CSL/ADAS WINTER CEREAL DISEASE SURVEYS, 2001**

The 2001 season was characterised by the very low levels of disease recorded. Of the **winter barley** diseases, *Rhynchosporium* leaf blotch remained the most severe and widespread, affecting on average 2.9% of the area of leaf 2 and recorded in 93% of crops. Levels of net blotch and brown rust equalled their lowest previously recorded in these surveys and powdery mildew levels were at their lowest ever recorded, all at 0.1% of the area of leaf 2 affected. Leaf spot, halo spot and yellow rust were recorded at trace levels. The percentage tillers affected by moderate plus severe lesions of eyespot (1.5%) was the lowest recorded since 1982. Of the **winter wheat** diseases, septoria leaf blotch (*S tritici*) was the most severe foliar disease, affecting 1.0% of the area of leaf 2 compared with 7.2% in 2000. Powdery mildew affected 0.1% of leaf 2, equalling the lowest ever levels recorded. Glume blotch was the only other disease to reach average levels of 0.1% area of leaf 2 affected. Brown rust and yellow rust were recorded at trace levels on both leaves 1 and 2. Moderate plus severe levels of eyespot, at 5.7%, were four times lower than the highest recorded levels in 2000. (Note that almost all crops surveyed have received fungicide treatment.)

- **MILDEW OF WHEAT**

Mildew levels were low in 2001, due to lack of conducive infection conditions. The wheat mildew population remains relatively unchanged, with one major pathotype and two similar ones predominating. The most common resistance genes (Pm2, Pm4b and Pm6) are ineffective for mildew control. Nearly 100% of mildew isolates tested could potentially infect *c.* 85% of the area of HGCA Recommended List winter wheat varieties, although many (*e.g.* Consort, Malacca) have good background resistance; the popular cultivars Claire and Option are susceptible. Shamrock was thought to have effective specific resistance but corresponding virulence has increased and its resistance rating has therefore dropped from 8 to 6.

- **YELLOW RUST OF WHEAT**

Very little yellow rust was found in farm crops during 2001. This was partly due to autumn and winter weather conditions being less favourable for yellow rust survival than in previous years. Perhaps a more important factor was that 75% or more of the wheat area was made up of resistant or moderately resistant varieties with ratings of 6 or above. This included the two most popular varieties Claire and Consort. At the same time, highly susceptible varieties with ratings of 3 had virtually disappeared from use. Nearly all the samples of yellow rust collected by the survey were found in untreated plots of variety trials. Tests of these indicated that the new race identified on Oxbow in 2000 is now becoming more common. It was also clear that this race can infect Consort, although it produces only moderate infection levels on this particular variety. This explains why Consort's yellow rust resistance rating has fallen from a figure of 9 on the HGCA Recommended List for 2001 to a figure of 6 for 2002. We also discovered that several newer varieties coming through the trials system are potentially very susceptible to this same race. These will be monitored closely during the coming season..

- **BROWN RUST OF WHEAT**

Brown rust was at low levels in 2001. Several of the currently recommended winter and spring wheats are highly resistant, although infected leaf samples were received from some crops which showed higher than expected disease levels. An isolate cultured from cv. Buchan infected seedlings of several resistant varieties. It also overcame, in controlled environment tests, the adult plant, temperature-sensitive resistance of the Thatcher-Lr backcross line Lr37. This gene is present in many UK and European wheat varieties and resistance conferred by it has so far remained effective in the field; this situation will be closely monitored.

- **MILDEW OF BARLEY**

The barley mildew population continues to become more complex, with over 90% of isolates tested capable of overcoming eight or more of the commonly used resistance genes. No new resistance genes or combinations were identified. The majority of winter barley varieties in current commercial use are potentially susceptible to the bulk of the mildew population. However, many cultivars have good non-specific resistance, indicated by their resistance ratings of 6 and above. Of the winter cultivars, only Vanessa, Leonie and Milena have effective specific resistance, matched by only 8% of the mildew population. The *mlo* gene remains the only effective specific resistance in spring cultivars; practically all spring barley cultivars currently grown in N. Ireland now contain this gene. The number of isolates giving low levels of infection on the *mlo* test cultivars continued to rise slightly, although no lack of control in the field has been recorded. Close monitoring of this "partial virulence" situation is vital.

- **YELLOW RUST OF BARLEY**

Despite 50% of the winter barley grown in the UK being potentially susceptible to yellow rust (resistance rating of 5 or less), the incidence of yellow rust in 2001 was again very low. The bulk of the spring barley area remains resistant to yellow rust, with 66% of the area sown to cultivars having a resistance rating of 6 or above. The three samples tested in 2001 were virulent on the BYR1 differential cultivar but were avirulent on the BYR2 and BYR3 differentials.

- **BROWN RUST OF BARLEY**

The highly resistant spring barley varieties County, Tavern, Adonis, Cellar and Static were seedling-susceptible to some isolates, all of which carried virulence for BBR-3. However, their adult plant resistances remained effective in the glasshouse and in field nurseries. Glasshouse adult plant tests again identified a group of winter barley varieties susceptible to a relatively 'simple' race (octal 273) but resistant to more complex races. The reasons for this are unclear. Several winter and spring barleys on the HGCA Recommended List expressed good levels of field resistance.

- **RHYNCHOSPORIUM OF BARLEY**

Leaf blotch was, as in recent seasons, the most severe and widespread foliar disease of barley. Virulence frequencies were similar to the previous year. Seedling tests suggest that the previously resistant cv. Pewter carries resistance factor BRR-8. Glasshouse tests with specific isolates of the pathogen identified several currently recommended and potential new winter varieties as carrying the race-specific resistance BRR-2. Adult plant field tests identified possible increased virulence to cv. Regina; higher than expected infection was also seen in plots in some areas. The current HGCA Recommended List spring barleys continue to be highly susceptible, with only cv. Pewter expressing resistance.

- **NET BLOTCH OF BARLEY**

Cultivars on the current HGCA Recommended List of winter barleys displayed a range of varying responses to the inoculum mixture against which they were tested. Cultivars Angela and Pearl were less heavily infected than would be expected from their disease ratings: they also showed relatively low levels of infection in similar tests in year 2000. Of the potential new cultivars, only cv. Sequel was resistant as a seedling.

- **SOIL-BORNE MOSAIC VIRUSES OF BARLEY**

Two mosaic viruses, *Barley yellow mosaic virus* (BaYMV) and *Barley mild mosaic virus* (BaMMV) are known to infect winter barley and both are widespread in the UK, although BaMMV is usually more common on malting varieties. A single resistance gene (*rym4*) confers resistance to both viruses in some UK varieties but since 1988 there have been about 25 outbreaks of a strain of BaYMV able to overcome this resistance. Only 19 barley samples infected with mosaic viruses were received in 2001, of which 17 contained BaYMV and 5 had BaMMV. Most samples were from cultivar Pearl and there were insufficient data to analyse differences in virus distribution between cultivars.

- **MILDEW OF OATS**

Mildew was late to establish in 2001, particularly in the winter crop. All isolates were identified as the widely virulent race 5 (OMV-1,2,3) which has been at a high frequency since the decline of the 'simpler' races 2, 3 and 4 during the 1970s. Current HGCA Recommended List winter varieties do not have good resistance to mildew, although spring varieties are more resistant.

- **CROWN RUST OF OATS**

Crown rust was at a much lower level in 2001 than in the previous season. The single isolate tested was identified as race 251, the most frequent race in recent years. It failed to infect the winter oat cv. Millennium which has a disease rating of 9 (highly resistant), although virulence to this variety has been identified previously. Current HGCA Recommended List winter and spring oat varieties have rather varying degrees of resistance to crown rust.

WINTER CEREAL DISEASE SURVEYS, 2001

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 399 randomly selected fields of winter barley and 416 fields of winter wheat were sampled as part of the 2001 national survey of cereal diseases. The season was characterised by the very low levels of disease recorded. The total foliar disease, that recorded on the top two leaves of winter barley (4.2%), was the lowest ever recorded. However, leaf blotch remained the most severe and widespread of the barley foliar diseases, affecting on average 2.9% of the area of leaf 2 and recorded in 93% of crops from the stratified sample. Although lower than the preceding three years levels were still higher than for any survey since 1983. Levels of net blotch and brown rust equalled their lowest previously recorded in these surveys and powdery mildew levels were at their lowest ever recorded, all at 0.1% of the area of leaf 2 affected. However, only the incidence of powdery mildew and septoria were lower than in any other survey. Leaf spot, halo spot and yellow rust were recorded at trace levels. The percentage tillers affected by moderate plus severe lesions of eyespot (1.5%), was the lowest recorded since 1982. Of the winter wheat diseases, septoria leaf blotch was the most severe foliar disease for the eleventh consecutive year affecting 1.0% of the area of leaf 2 compared with 7.2% in 2000, this being the lowest level since 1995 (0.8%). Septoria leaf blotch was also present at trace levels on the ears. Powdery mildew was the next most common and severe foliar disease, recorded in 26% of the stratified sample and affecting an average area of 0.1% of leaf 2, equalling the lowest ever levels recorded in 2000 and 1998. It was also recorded at trace levels on leaf 1 and the ear. Glume blotch was the only other disease to reach average levels of 0.1% of leaf 2 affected, it was also present at trace levels on the ear. Brown rust levels declined, its incidence and severity being lower than in any survey since 1996. Yellow rust was recorded at trace levels on both leaves 1 and 2 but was absent from the ear. Didymella leaf spot was also recorded at trace levels. Overall total foliar disease levels were the lowest since the 1995 survey. Moderate plus severe levels of eyespot were four times lower than the highest recorded levels of 2000. 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 1984 (Hardwick *et al.*, 1998, 2000a, 2000b, 2001a, 2001b; 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 2000-2001 growing season, and includes information on fungicide use. The results are compared, where appropriate, with those from previous years.

METHODS

The 2001 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) (Zadoks *et al.*, 1974).

The regional divisions used are those based on Government Office Regions (Table 1).

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 2000 MAFF agricultural census and excluding those from within a 3km radius of premises affected by Foot and Mouth disease. Problems in sampling from areas in the affected counties resulted in a reduced sample size from the North East, North West and West Midlands regions for winter barley and the North East and West Midlands for wheat. Otherwise the distribution of farms between regions was proportional to the regional area of winter barley and wheat grown and on the size of the arable area of the farms to be surveyed. There was an exception for Wales where additional addresses were requested in order to obtain sufficient sites for data comparison. A total of 399 randomly selected fields of winter barley and 416 fields of winter wheat were sampled and assessed. Calculation of the national results, based on a stratification according to location and farm size, resulted in utilisation of data from 283 and 325 samples of winter barley and winter wheat, respectively. A questionnaire providing 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

Only one foliar disease, leaf blotch (*Rhynchosporium secalis*), exceeded 0.1% area of leaf 2 affected at 2.9% (Table 2), this compared with 5.2% in 2000. It was the most widespread disease with a national occurrence of 93% of samples affected, a similar figure to 2000. Net blotch (*Pyrenophora teres*) and brown rust (*Puccinia hordei)* were at their lowest levels since 1990 and 1996, respectively and powdery mildew (*Blumeria graminis*) at the lowest level ever recorded, all at 0.1% area of leaf 2 affected. (Fig. 1). Leaf spot (*Septoria* spp.), halo spot (*Pseudoseptoria donacis*) and yellow rust (*Puccinia striiformis*), recorded in four crops from the stratified sample, were all at trace levels.

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

	Leaf 1	Leaf 2
Powdery mildew	tr	0.1
Brown rust	tr	0.1
Net blotch	tr	0.1
Leaf blotch	0.9	2.9
Leaf spot	tr	tr
Halo spot	tr	tr
Yellow rust	tr	tr
Insect damage	0.3	0.3
Green leaf area	96.8	91.6

tr = trace (< 0.05)

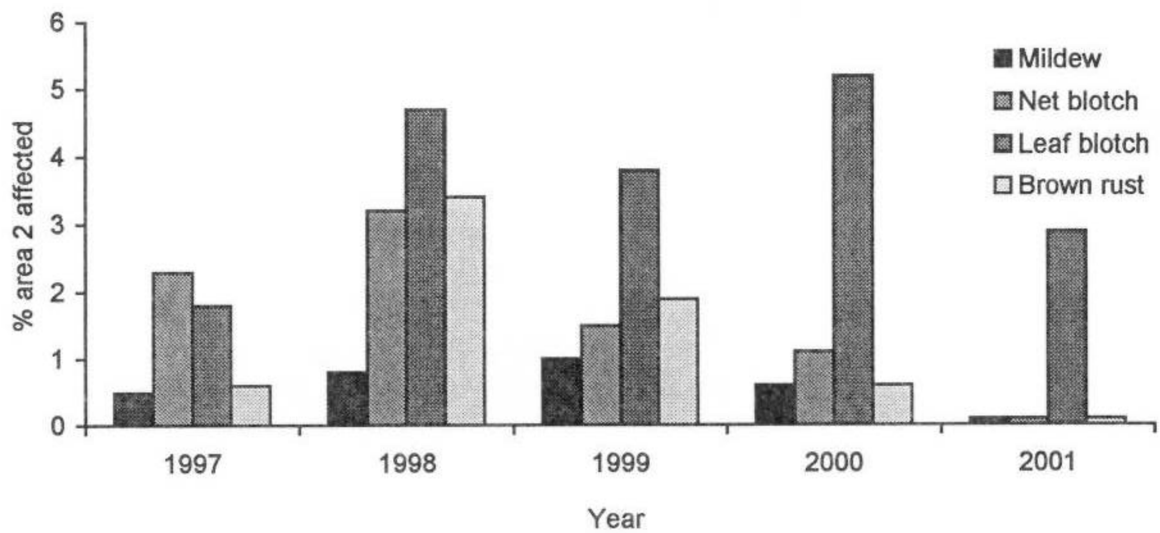

Fig. 1. National foliar disease levels (mean % area leaf 2 affected)

Eyespot (*Pseudocercosporella herpotrichoides*) was recorded in 46% of crops, which was less frequently than in any survey since 1982 (42%). It was also less severe than in any survey since then with 1.5% of stems affected by moderate and severe symptoms compared to 17.9% in 2000, 9.2% in 1999 and 1.2% in 1982. Sharp eyespot (*Rhizoctonia cerealis*) was recorded less frequently and was less severe than in any previous survey, recorded in 12% of crops sampled with moderate and severe symptoms affecting 0.3% of stems compared with the previous low of 0.9% of stems in 1994. Symptoms of fusarium (*Fusarium* spp.) were present in 77% of crops, with moderate and severe levels on 2.2% of stems compared with 12% in 2000, 4.7% in 1999 and 10.5% in 1998 (Table 3).

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

	Slight	Moderate	Severe
Eyespot	5.2	1.5	tr
Sharp eyespot	0.7	0.2	0.1
Nodal fusarium	7.2	1.7	0.0
Internodal fusarium	4.0	0.7	tr
All fusarium	10.1	2.2	tr

Regional disease severity

The highest levels of powdery mildew were recorded in the North East where Regina was the predominant cultivar (resistance rating 3, Anonymous, 2001). Net blotch was most severe in the South West (0.3% area leaf 2 affected). The severity of brown rust (*Puccinia hordei*) was highest in the Yorkshire and the Humber, East and South West regions, affecting an average of 0.1% area on leaf 2. Leaf blotch was most severe in the North West with 9.3% average area of leaf 2 affected, and least severe in the South East region (Table 4). Leaf blotch affected all samples from the North West and West Midlands regions and did not fall below 82% in any of the other regions. Halo spot was only recorded at trace levels in Wales. Leaf spot was most prevalent in the South West. Yellow rust (*Puccinia striiformis)* was recorded in one sample from Yorkshire & the Humber region and three from the East Midlands.

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

Region	No. of samples	Powdery mildew	Brown rust	Net blotch	Leaf blotch	Leaf spot	Halo spot	Yellow rust
NE*	18	0.2	0.0	0.1	2.5	0.0	0.0	0.0
NW*	3	0.0	tr	0.2	9.3	0.0	0.0	0.0
Y & H	71	0.1	0.1	tr	1.8	0.0	0.0	tr
EM	59	0.1	tr	tr	3.4	0.0	0.0	tr
WM*	29	0.1	tr	0.1	5.6	tr	0.0	0.0
EAST	96	0.1	0.1	0.1	1.9	tr	0.0	0.0
SE	40	0.1	tr	0.1	1.6	0.0	0.0	0.0
SW	60	0.1	0.1	0.3	3.5	tr	0.0	0.0
WALES	23	tr	0.0	tr	3.0	0.0	tr	0.0
National (stratified)	283	0.1	0.1	0.1	2.9	tr	tr	tr

* reduced sample size

Effect of cultivar on disease severity

Two cultivars Pearl and Regina accounted for 57% of the national stratified sample with 29% and 28% respectively followed by Jewel with 7%. This represented a 24% increase for Pearl and an 11% decline for Regina compared with 2000. Of the seven most common cultivars in the stratified sample the highest level of leaf blotch was recorded on Intro at 7.9% of the area of leaf 2 affected (resistance rating 6) (Anonymous, 2000) and the lowest on Pearl at 1.2% of the area of leaf 2 (resistance rating 8). Brown rust was most severe on Vanessa, affecting 0.3% area of leaf 2 (resistance rating 4). The highest net blotch levels were found on Regina with 0.2% area of leaf 2 affected (resistance rating 7) and the highest powdery mildew levels of 0.1% were recorded on Regina, Jewel, Heligan and Intro (Fig. 2). Yellow rust was record on cultivars Heligan (resistance rating 5), Jewel (resistance rating 8), Intro (resistance rating 5) and Regina (resistance rating 2).

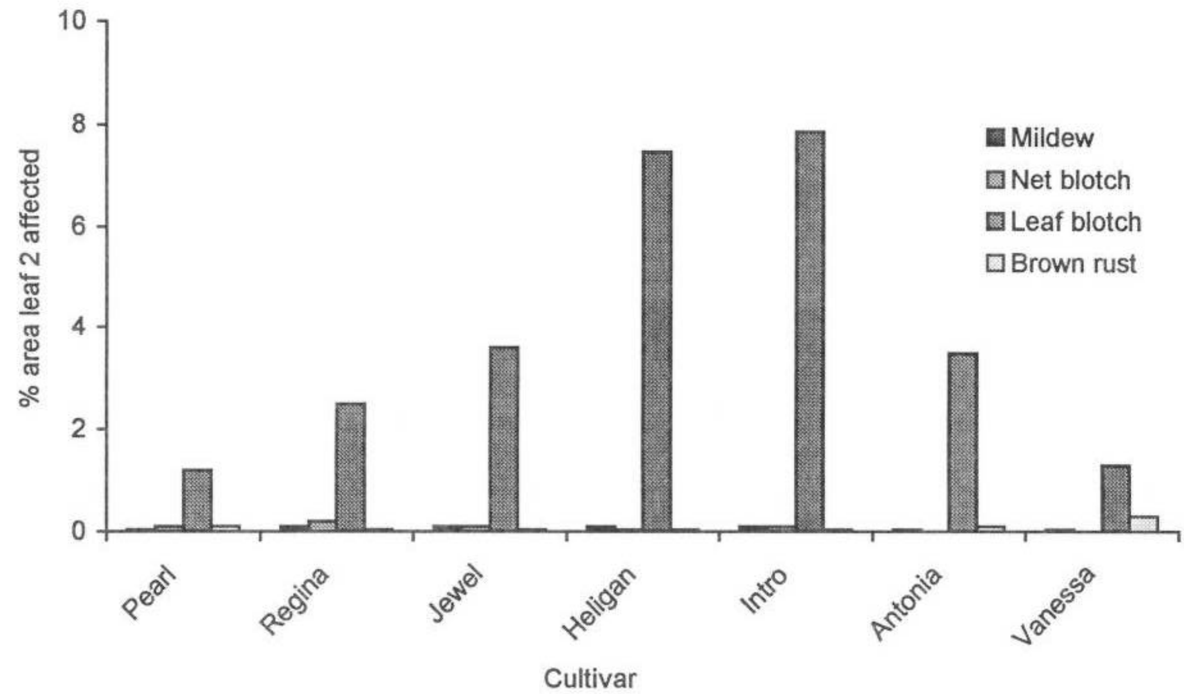

Fig. 2 Foliar diseases on main cultivars (mean % area leaf 2)

The proportion of cultivars sown with a resistance rating of 5 or less (those considered to be susceptible to disease) for leaf blotch has shown a decline from 1999 (Fig.4). The proportion for crops with a resistance rating of 5 and below for net blotch increased dramatically from 8 to 37%. This was due to the increased area sown with Pearl, with a resistance rating of 5. The situation with powdery mildew has generally resulted in a national crop with levels above 40% and, in 2000, peaking at 69%. However, the decline in Regina (resistance rating 3) and the increase in Pearl (resistance rating 8) grown has resulted in a substantial fall in the percentage of crops sown with a resistance rating of 5 and below for powdery mildew. However, the fluctuation in the proportion of crops with low resistance ratings does not accurately mirror those of the diseases.

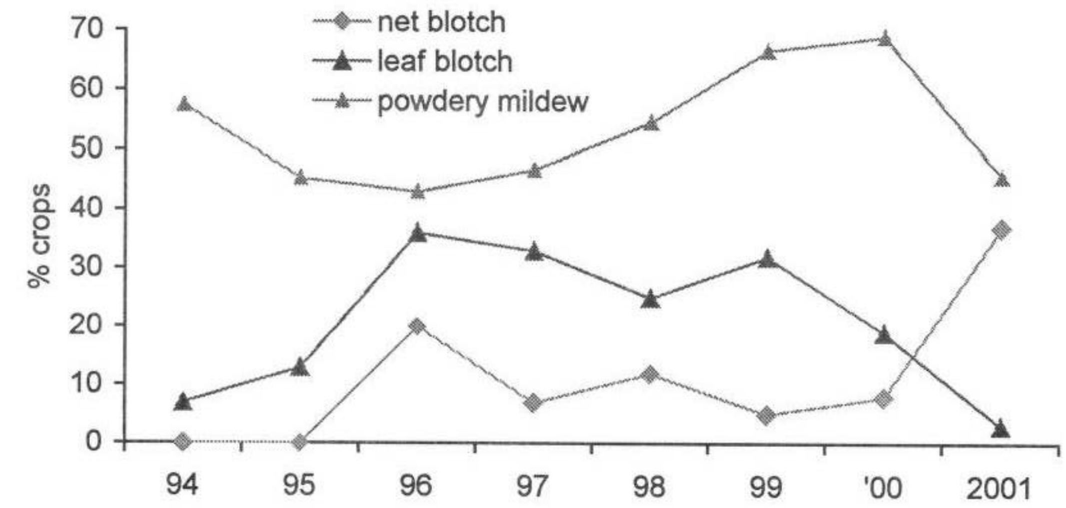

Fig. 3. Percentage crop sown with a resistance rating of 5 and less for powdery mildew, net blotch and leaf blotch.

Sowing date and disease

There were fewer early sown crops (before 24 September) recorded in this survey than ever before and fewer crops were sown between 24-30 September than in any survey since 1993. Almost 30% of crops were sown after 14 October with almost 5% of these sown after the end of the year. Generally, total foliar disease levels on leaf 2 were more severe in crops drilled between 24 and 30 September. Eyespot was more common in crops sown before 24 September and its severity decreased in the later sown crops. Eyespot was more damaging in crops which followed a cereal. Sharp eyespot was more severe in crops drilled before 30 September.

Fungicide use

Fungicide sprays were used on 96% of crops with a mean of 1.6 sprays per crop (compared with 95% and 1.7 in 2000, respectively). Three per cent of crops were treated with a fungicide before the end of tillering, 80% at or around the first node development stage (GS 31) and 70% at or after flag leaf emergence (GS 37). Thirty six per cent of crops received a single spray, 67% at *c.* GS 31. Fifty four per cent were sprayed twice, with the majority (89%) at GS 31 with the second spray at or after GS 37 (flag leaf emerging). Six per cent of crops received three fungicide sprays, a decrease of 2% when compared to the 2000 survey. No crop received more than three applications. The most commonly applied fungicide products were Amistar (183 applications), Unix (103 applications), Opus (89 applications) and Mantra (49 applications). The number of different foliar applied fungicide products totalled 62 with 24 active ingredients. Seventy two per cent of crops in the survey were grown from certified seed, and 89% of all crops were known to be grown from fungicide treated seed with 2% of growers unable to specify seed treatments.

Winter wheat

Severity of foliar and stem disease

Nationally, the total foliar disease level was lower than in any year since 1995. Septoria leaf blotch (*Septoria tritici*, teleomorph: *Mycosphaerella graminicola)* was for the eleventh consecutive year the most severe foliar disease. Glume blotch (*Stagonospora nodorum*, teleomorph: *Phaeosphaeria nodorum*) and powdery mildew (*Blumeria graminis*) both affected 0.1% of the area of the second leaf but only at trace levels on leaf 1 and the ear (Table 5). Brown rust (*Puccinia recondita*), yellow rust (*Puccinia striiformis*) and *Didymella exitalis* were all recorded at trace levels on both leaves. Fusarium ear blight (*Fusarium* spp.) symptoms were recorded in 20% of samples compared with 38% in 2000, 33% in 1999, 61% in 1998, 22% in 1997 and 2% in 1996.

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

	Leaf 1	Leaf 2	Ear
Powdery mildew	tr	0.1	tr
Septoria leaf blotch	0.1	1.0	tr
Glume blotch	tr	0.1	tr
Yellow rust	tr	tr	0.0
Brown rust	tr	tr	-
Didymella	tr	tr	-
Cephalosporium	0.0	0.0	-
Tan spot	0.0	0.0	-
Insect damage	0.6	0.5	-
Green leaf area	93.9	88.5	-

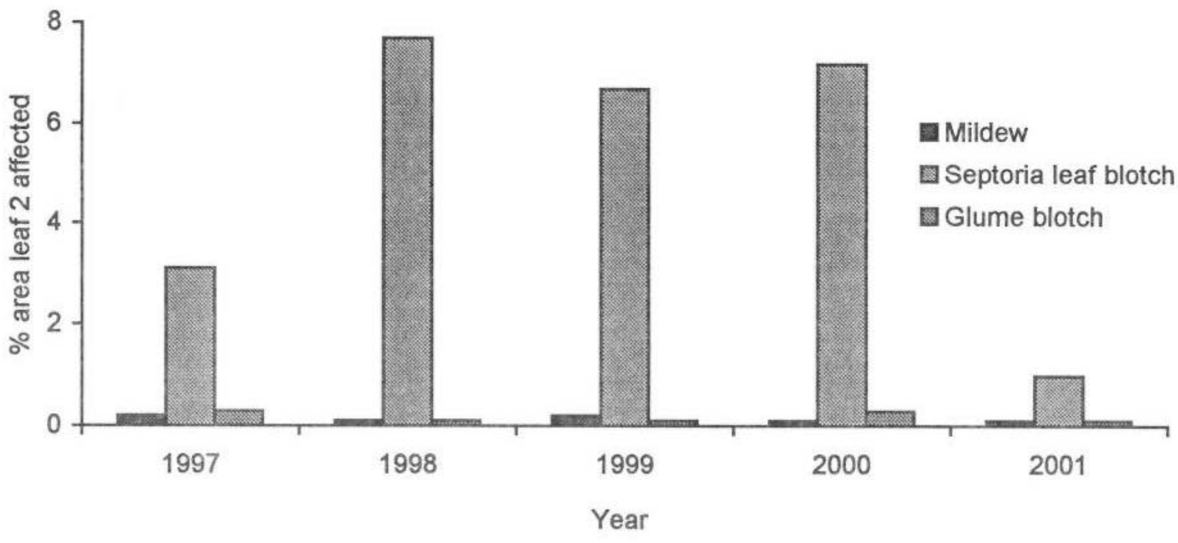

Fig. 4. National foliar disease levels (mean % area leaf 2 affected), 1997-2001.

The level of eyespot, at 5.7% stems affected with moderate and severe symptoms, was the lowest since 1996 and four times lower when compared with the 22.9% recorded in 2000. (Table 6, Fig 5). Moderate and severe symptoms of sharp eyespot affected 2.3% of stems, which were lower than those recorded in the previous four surveys, with 3.1%, 4.6%, 4.6% and 4.2% of stems respectively. (Fig. 6). The fusarium complex affected 22.5% of stem bases, which was a similar figure compared with 2000 (Table 6).

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

	Slight	Moderate	Severe
Eyespot	9.4	5.6	0.1
Sharp eyespot	4.2	2.1	0.2
Nodal fusarium	8.2	3.0	0.1
Internodal fusarium	10.4	3.7	0.1
All fusarium	16.2	6.1	0.2

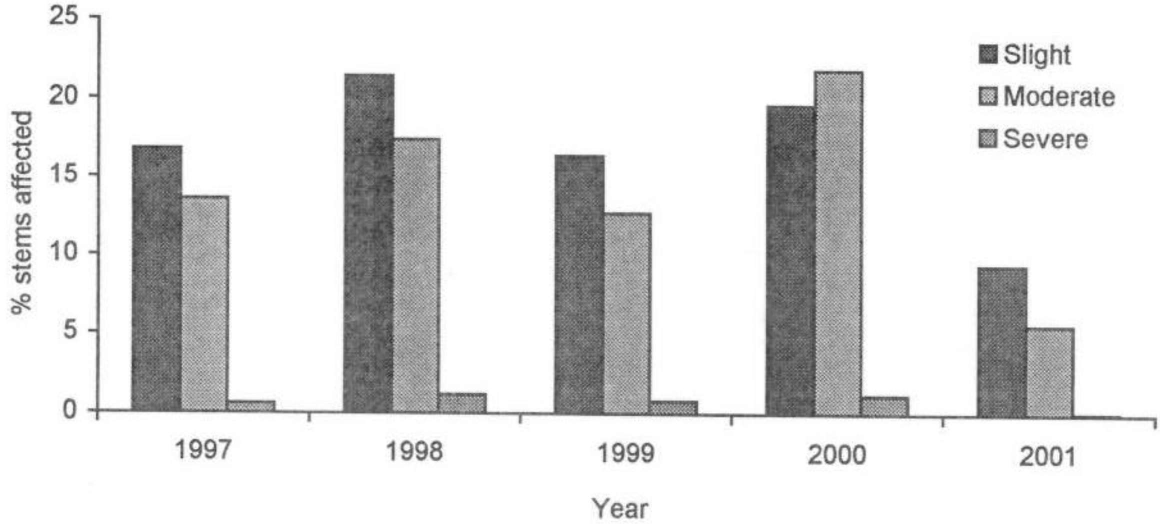

Fig. 5. National levels of eyespot (mean % stems affected).

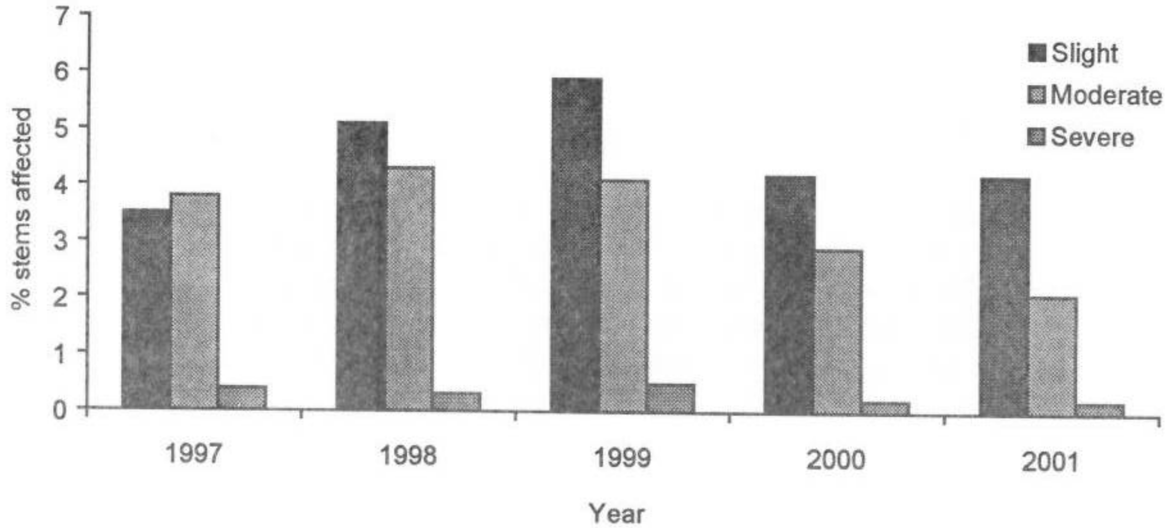

Fig. 6. National levels of sharp eyespot (mean % stems affected).

Table 7. National fusarium levels on the ears.

Year	% samples affected		% ears affected	
	Ear blight	Glume spot	Ear blight	Glume spot
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
1999	33.1	48.0	3.4	5.4
2000	37.8	44.6	4.9	4.7
2001	19.7	31.1	2.2	3.2

Take-all was present in 22% of crops. Take-all patches were recorded in 7% of crops compared with 11.5% in 2000, 12.6% in 1999, 17.7% in 1998 and 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 (2000)	207.0	62.0	20.0	9.0	6.0	97.0
Per cent of total (2000)	68.1	20.4	6.6	3.0	2.00	31.9
Number of crops (2001)	246.0	47.0	16.0	4.0	2.0	69.0
Per cent of total (2001)	78.1	14.9	5.1	1.3	0.6	21.9

* 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

Symptoms of BYDV were recorded in 12% of crops with the majority 89% recorded as category 1 (a scattering of plants showing symptoms) (15% and 93%, respectively in 2000). The remaining 11% had small patches of BYDV. No crops were recorded as having symptoms which fell into categories 3 (between 1 and 10% of the field affected) or 4 (more than 10% of the field affected).

Regional disease incidence and severity

The highest levels of septoria leaf blotch were found in the Yorkshire and the Humber, West Midlands and the South West regions. The lowest levels were in the South East where the incidence of the disease was only 50% of samples affected compared with the highest incidence of over 75%. Only the three main foliar diseases were recorded in every region. Levels of powdery mildew did not exceed more than 0.3% of leaf 2 affected (North East and North West regions) and glume blotch was only at 0.2% of leaf 2 affected in the Yorkshire & Humber region. Brown rust levels were low in all regions where it was recorded, it was not recorded in samples from the North East, North West and Wales. Yellow rust was only recorded in samples from the East Midlands region where average levels of 0.1% of the area of leaf 2 were reached (Table 9).

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

Region	No. of samples	Powdery mildew	Septoria leaf blotch	Glume blotch	Yellow rust	Brown rust	*Didy -mella*	Tan spot	*Cephalo -sporium*
NE*	15	0.3	0.8	0.1	0.0	0.0	0.0	0.0	0.0
NW	7	0.3	1.1	tr	0.0	0.0	0.0	0.0	0.0
Y&H	56	0.2	2.0	0.2	0.0	tr	tr	0.0	0.0
EM	73	0.1	0.6	0.1	0.1	tr	0.0	0.0	0.0
WM*	28	0.3	2.0	tr	0.0	tr	tr	0.0	0.0
EAST	111	0.1	1.2	tr	0.0	tr	0.0	0.0	0.0
SE	58	tr	0.2	tr	0.0	tr	0.0	0.0	0.0
SW	47	tr	1.2	tr	0.0	tr	tr	0.0	0.0
WALES	21	0.2	0.6	tr	0.0	0.0	0.0	0.0	0.0
National (stratified)	325	0.1	1.0	0.1	tr	tr	tr	0.0	0.0

* reduced sample size

Levels of moderate plus severe eyespot were highest in the Yorkshire and the Humber region where the incidence of eyespot was over 87%. Overall moderate plus severe levels were generally highest on samples from the north when compared with the midlands, east and south and west.

Moderate plus severe sharp eyespot levels were most severe in the North East region. The lowest levels were recorded in samples from the South East.

Effect of cultivar on disease severity

The top two most popular cultivars in the stratified sample accounted for more than 50% of the total. Claire with 33% was, for the first time, the most commonly sampled cultivar in the survey with a 14% increase compared with 2000; it was the most frequently sampled cultivar in all regions. It was followed by Consort, last year's top cultivar, with 21% of the sample which was only a 3% decrease from 2000. In third place was Malacca the only other cultivar with more than 10% of the sample. Savannah showed the highest levels of septoria leaf blotch, with 1.7% area of leaf 2 affected followed by Consort with 1.6% area of leaf 2 affected (both resistance rating 4). Powdery mildew was most severe on Hereward, with 0.4% area of leaf 2 affected (resistance rating 6) and glume blotch was most severe on Equinox with 0.2% area of leaf 2 affected (resistance rating 6) (Fig. 7).

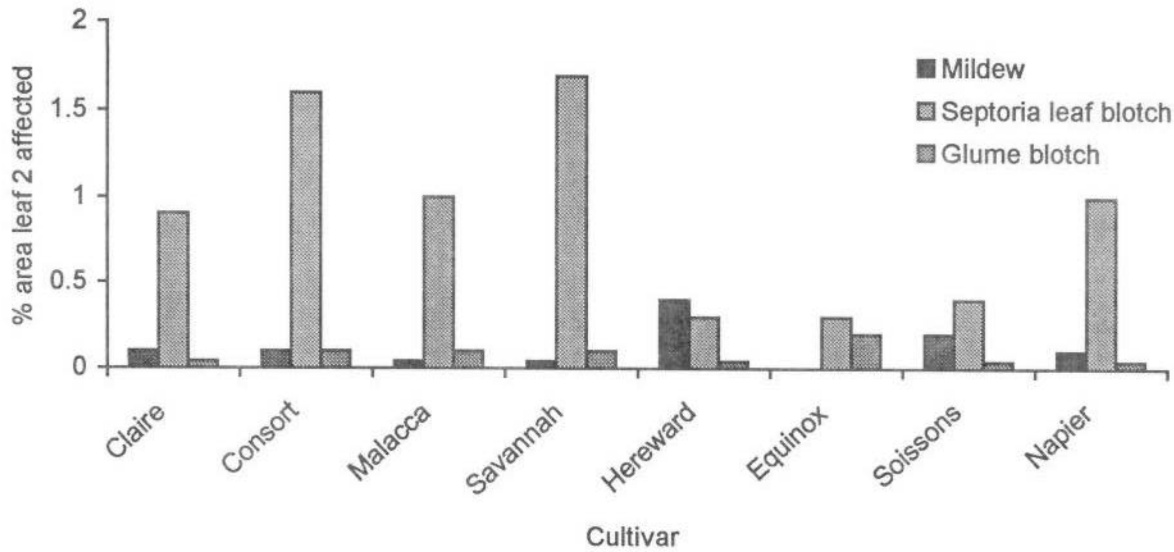

Fig. 7. Foliar diseases on main cultivars (mean % area leaf 2).

The proportion of cultivars with a resistance rating of 5 of less (those considered to be susceptible to disease) for septoria leaf blotch and glume blotch decreased from 1999 and that of powdery mildew increased. This is was a reflection of the increased area sown with Claire, which had a resistance rating for septoria leaf blotch and glume blotch of 7 and powdery mildew rating of 4 (Fig. 8). As with winter barley, the fluctuation in the proportion of crops with low resistance ratings did not accurately mirror those of the diseases.

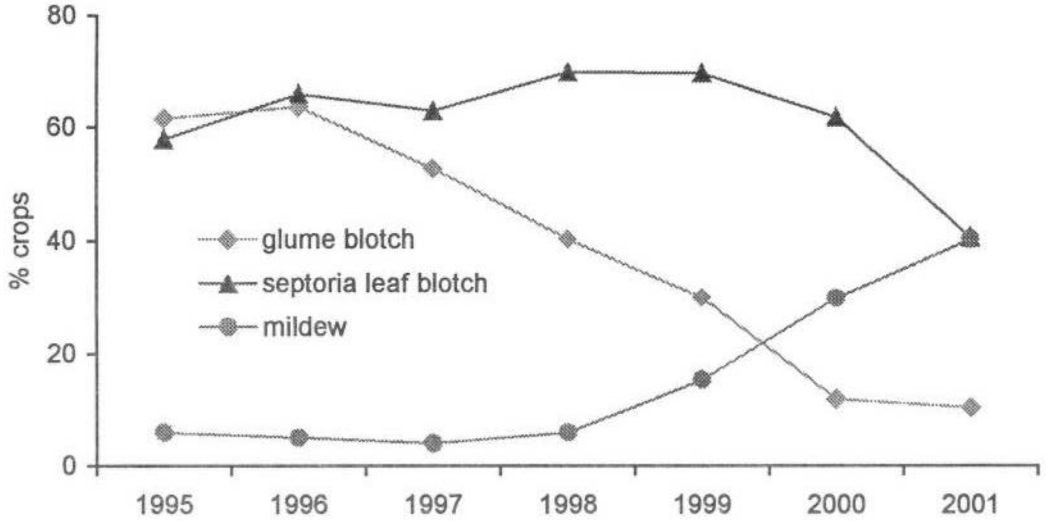

Fig. 8. Percentage crops sown with a resistance rating of 5 and less for glume blotch, septoria leaf blotch and powdery mildew

Previous cropping, sowing date and disease

The majority of crops followed a cereal or an oilseed rape crop (35% and 23% respectively). The highest levels of eyespot were found in crops following set-aside or pulse/legume. After eighteen successive years the lowest levels of eyespot were not found after grass but were recorded on crops which followed another cereal. Only seven crops in the stratified sample followed grass (2% of sample) and levels of eyespot were low except for a crop of Soissons (resistance rating 4) from the South West region where it was noted that severe eyespot infection caused whiteheads. Sharp eyespot levels were most severe following potatoes and least severe after wheat. Moderate and severe levels of fusarium stem base diseases were lowest following grass and highest after seta-side. The incidence and severity of take-all was greatest in crops following wheat. Take-all was not recorded on crops which followed grass. Monoculture had no obvious influence on foliar disease severity and little effect on levels of the stem base diseases or take-all, although sharp eyespot was more severe in first wheats. The consistent effect seen in past surveys has been a reduction in eyespot severity seen in crops following a non-cereal break compared to levels in crops following a cereal. In the 1999 and 2001 surveys the highest levels of moderate plus severe eyespot were recorded in crops where a break of two or more years occurred. In both years sowing was delayed by poor conditions with 17% and 20% respectively sown after 31 October. However, drilling was also delayed in the wet autumn of 1993 but the trend continued as expected in the 1994 survey. Take-all symptoms were more prevalent in crops where no break had occurred. For the first time in these surveys more than 10% of the stratified sample comprised of crops sown after 31 December. There was no obvious effect of sowing date on foliar disease levels although for those crops sown after 31 December levels of septoria leaf blotch were lower and powdery mildew levels increased. Eyespot was less severe in crops drilled after October a trend seen in 72% of surveys since 1975.

Fungicide use

Fungicide sprays were used on 98% of crops, with 86% of crops receiving a spray at around GS 31, 79% at GS 39 and 53% at GS 59. Crops received on average 2.4 fungicide spray applications (2.5 in 2000). Two or more treatments were applied to 88% of crops (91% in 2000). The most popular spray programme, applied to 28% of crops, were three sprays, with the first spray aimed at GS 31, a second spray at GS 39 and a third at GS 59. The most popular two-spray programme, applied to 27% of all crops, was a first spray aimed at GS 31, followed by a second aimed at GS 39. The most commonly applied fungicide products were Amistar (219 applications), Opus (155 applications), Landmark (138 applications), and Folicur (106 applications). The number of different foliar applied fungicide products totalled 76 with 29 active ingredients. Sixty five per cent of crops were grown from certified seed with 89% of crops sown with fungicide treated seed and 3% of growers unable to specify seed treatments.

Sixty two per cent of crops were treated with insecticides, the majority (70%) received a single spray, mostly spring applied (44%). The proportion of crops receiving a summer-applied insecticide increased compared with those from recent surveys. This was probably due to the perceived vulnerability of later sown crops to pest attack and particularly the threat of wheat blossom midge following a late spring and cool early summer conditions.

DISCUSSION

The overall levels of disease recorded in 2001 were much lower than previous years. One of the causes was the later sowing of crops, more evident in winter barley than winter wheat. With both crops there were reduced sowings before the middle of September and more after mid-October. Those diseases, which can be markedly affected by drilling date, BYDV and take-all, were lower. However, there was not a good correlation between sowing date and disease severity.

There were two disturbing features of both surveys. The first was that the level of fungicide input in both wheat and barley remained much the same as in previous years, despite the lower severity of disease. Cook & King (1984) indicated that final disease levels were often similar in treated and untreated crops and it is more likely, therefore, that the lower disease levels recorded were a reflection of the season and not of a sudden improvement in fungicide efficacy or application. This implied that farmers were applying fungicides just as an insurance and taking no account of disease risk. This would seem to be an indication that research into identifying risk is not being noted by the farming community and various agencies ineffectiveness in promoting the results. The second is the increased reliance on a limited number of cultivars. Just two cultivars occupied more than 50% of the area sown each to winter wheat and winter barley. The encouraging fact is that Claire has moderate resistance to the dominant diseases, septoria leaf blotch and eyespot but its low resistance rating to powdery mildew could mean a resurgence of this disease. The popularity of Pearl has resulted in an increase in the percent of the national crop with a low level of resistance to net blotch and it important that this disease is monitored carefully.

ACKNOWLEDGEMENT

The project was funded by DEFRA.

REFERENCES

Anonymous (2000). UK recommended lists for Cereals 2000. Cambridge, UK: NIAB.

Cook RJ, King JE, 1984. Loss caused by cereal diseases and the economics of fungicidal control. In: Wood RKS, Jellis GJ. eds. *Plant Diseases: Infection, Damage and Loss.* Oxford, UK: Blackwell Scientific Publications, 237-45.

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

Hardwick, N.V., Jones, D.R. & Slough J.E. (2001a). Factors affecting diseases of winter wheat in England and Wales, 1989-1998. *Plant Pathology* **50**, 453-462 and Erratum, 650-652.

Hardwick, N.V., Slough J.E & Jones, D.R. (2000a). CSL/ADAS winter wheat and winter barley disease surveys, 1999. *United Kingdom Cereal Pathogen Virulence Survey 1999*. Cambridge UK: UKCPVS, 8-21.

Hardwick, N.V., Slough, J.E. & Jones D.R. (2000b). Cereal disease control - are fungicides the sole answer? Proceedings BCPC Conference, Pests & Diseases, 2000. Brighton, UK: BCPC, 647-654.

Hardwick, N.V., Slough, J.E. & Jones, D.R. (2001b). Winter cereal disease surveys, 2000. *United Kingdom Cereal Pathogen Virulence Survey 2000.* Cambridge UK: UKCPVS, 8-20.

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.

Zadoks, J.C., Chang, T.T. & Konzak, C.F. (1974). A decimal code for the growth stage of cereals. *Weed Research* **14**, 415-421.

MILDEW OF WHEAT

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

NIAB, Huntingdon Road, Cambridge CB3 0LE

Mildew levels were low in 2001, due to lack of conducive infection conditions. The population remains relatively stable, with one major pathotype and two similar ones predominating. The most common resistance genes Pm2, Pm4b and Pm6 are matched by very high virulence frequencies in the pathogen population. Nearly 100% of mildew isolates tested could potentially infect *c.* 85% of the area of HGCA Recommended List winter wheat cultivars, although some (e.g. Consort, Malacca) have good partial resistance; the popular cultivars Claire and Option are susceptible. Shamrock was thought to have effective specific resistance but corresponding virulence has increased and its resistance rating has therefore decreased from 8 to 6.

INTRODUCTION

2001 saw very low levels of powdery mildew in winter and spring wheat crops. This was due to wet autumn and spring conditions and longer spells of cold winter weather than in recent years. This resulted in low sample numbers (similar to 1998 and 1999) being received, in contrast to the good numbers of samples in the 2000 survey. The majority of samples were collected relatively late in the season, *viz.* June-July, and were mostly from trial plots.

METHODS

96 samples were collected from 29 winter cultivars, one spring cultivar and one unknown spring breeding line in 2001. Single colony isolates were successfully recovered from 89 samples. The source cultivars of the tested isolates are shown below:

Winter cultivars	No. of isolates		No. of isolates		No. of isolates
Shamrock	22	Rialto	4	Madrigal	2
Claire	19	Soissons	4	Malacca	2
Solstice	13	Xi 19	4	Napier	2
Storm	12	Deben	3	Oxbow	2
Richmond	11	Fender	3	Riband	2
Phlebas	9	Hereward	3	Savannah	2
Chatsworth	8	Biscay	2	Tanker	2
Macro	8	Buchan	2		
Access	7	Charger	2	Spring cultivars	
Genghis	4	Consort	2	Chablis	2
Option	4	Equinox	2	Unknown breeding line	1

The samples were collected from the following locations:

	No. of isolates		No. of isolates
Headley Hall, N Yorks.	58	Gwent, S Wales	12
Morley, Norfolk	29	Aberystwyth, Wales	3
NIAB, Cambridge	29	Harper Adams, Shropshire	2
Spalding, Lincs.	16	Rothwell, Lincs.	2
Cockle Park, Northumberland	13	Itchen Stoke, Hants.	1
Total			**165**

Isolates were inoculated onto detached leaf segments of differential cultivars using a spore settling tower and infection assessed according to the method of Moseman *et al*, 1965. The differential cultivars containing specific resistance genes/factors which were used to test for corresponding specific virulence genes/factors are shown in Table 1.

Table 1. Differential cultivars used to determine virulence genes in isolates of wheat mildew, 2001.

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	Unknown
Axona	MlAx	Unknown
Soissons	MlSs*	Unknown
Shamrock	MlSh*	Unknown

* tentative designations for specific resistance factors

The winter cultivar Phlebas (Pm6 + ?) and the spring cultivar Status (resistance unknown) were also included in some tests.

RESULTS AND DISCUSSION

Virulence frequencies

V2, V4b and V6 were detected in all isolates tested (Table 2): a large proportion of the wheat acreage selects for these virulence factors (75%, 62% and 56% respectively). The most popular cultivars, Claire (Pm2,Pm4b), Consort and Malacca (both Pm2,Pm4b,Pm6) select for various combinations of these virulences. V8 remains at high frequency in the population, although the area of cultivars carrying Pm8 has been decreasing since 1998. Frequencies of V5 and VTa2 also remain high in the population, although there has been no selection for these virulences since the decline of Mercia (pm5,Ta2)

Table 2. Frequency of wheat mildew virulence factors 1995-2001 and 2001 areas of winter cultivars with the corresponding resistance.

	Frequency of virulence factors (%)							% area
Virulence factor	1995	1996	1997	1998	1999	2000	**2001**	**2001#**
2	99	100	100	100	100	100	**100**	**75**
3b	4	3	4	1	2	1	**4**	**0**
4b	88	93	98	100	99	99	**100**	**62**
5	92	93	95	88	91	88	**90**	**0**
6	89	96	99	100	100	99	**100**	**56**
8	95	96	98	97	99	97	**98**	**15**
17	10	15	16	8	22	2	**9**	**0**
d	19	33	26	18	6	12	**25**	**<1**
2,Ta2	85	92	93	86	97	96	**95**	**0**
To	18	29	29	16	16	5	**24**	**<1**
Br	21	32	30	16	15	8	**24**	**0**
5,Si2	22	32	21	17	20	8	**8**	**0**
So	10	15	15	10	6	4	**6**	**0**
Ax	11	24	20	7	1	1	**10**	**2**
Ss				65	57	74	**82**	**2**
Sh				3	0	4	**16**	**2**
Number of isolates tested	265	313	328	187	148	286	**165**	

NIAB (2001)

Virulence for Mld increased in frequency in 2001, as did virulence for MlAx, MlTo and MlBr. Since no current commercial winter cultivars were thought to select for these virulences, the increase is probably due to sampling bias. New HGCA Recommended List candidate cultivars are particularly targeted when sampling: *e.g.* isolates collected from Xi 19 (thought to carry MlAx) in 2001 also carried Vd, VTo and VBr . As all isolates in which VAx has been detected also carry Vd and VBr, it appears likely that all cultivars carrying MlAx carry Mld and MlBr. The presence of VTo in isolates carrying VBr is probably a result of common selection by spring cultivar Tonic in the late 1980s (50% of the spring wheat grown in 1989 was Tonic). As all isolates carrying VTo also carry VBr, it is probable that Tonic carried both MlTo and MlBr.

Samples from neighbouring cultivars in the trials also yielded isolates with similar virulence spectra.
V3b, V17, VSi2 and VSo remain at low frequencies in the population despite no known selection. VSs was detected in 82% of the isolates tested, a slight increase from 2000, although Soissons represented only 2% of the winter wheat grown in 2001.

Shamrock carries unknown specific resistance not represented by the differentials used in these tests. For convenience, the epithet MlSh has been adopted to denote this resistance. VSh was detected in 16% of isolates tested, a fourfold increase over the 2000 figure. However, although infection on Shamrock was common in trials compared to other cultivars, the increase in virulence frequency observed in 2001 was probably due in part to sampling bias, as 13% of the isolates tested originated from Shamrock. Although Shamrock carries specific resistance matched by only 16% of the population tested, the frequency of corresponding virulence appears to be increasing and the level of non-specific resistance is thought to be low.

Frequency of pathotypes

V2,4b,5,6,8,Ta2 remains the dominant pathotype, although its frequency has decreased this year (Table 3). However, two pathotypes which have increased in frequency, V2,4b,5,6,8,Ta2,To,Br and V2,4b,5,6,8,d,Ta2, include this most common virulence combination.

Table 3. Frequencies of the most commonly identified pathotypes, 1993-2001, as defined by the factors in Table 1, with the exception of MlSs (Soissons) and MlSh (Shamrock).

	Frequency of pathotypes (%)								
Pathotype	1993	1994	1995	1996	1997	1998	1999	2000	**2001**
2,4b,5,6,8	6	8	8	4	3	9	<1	2	**1**
2,4b,6,8,Ta2	1	2	3	1	2	6	5	8	**5**
2,4b,5,8,Ta2	4	4	2	1	<1	0	0	1	**0**
2,4b,5,6,8,Ta2	25	26	38	35	42	38	57	61	**41**
2,4b,5,6,8,Ta2,To,Br	4	5	6	4	7	5	9	1	**10**
2,4b,5,6,8,Ta2,Si2	0	2	4	6	4	5	11	2	**1**
2,4b,5,6,8,Ta2,Si2,So	8	6	8	4	7	4	2	2	**3**
2,4b,5,6,8,d,Ta2	2	7	5	5	3	6	2	7	**12**
2,4b,5,6,8,d,Ta2,To,Br,Ax	2	3	3	6	10	1	<1	1	**5**
Number of pathotypes	78	71	57	59	44	35	22	37	**44**
Number of isolates	356	347	265	313	328	187	148	286	**165**

Complexity of isolates

The number of virulence factors carried is still increasing (Table 4). Although only 47% of isolates had 6 factors, compared with 63% in 2000, 42% of isolates carried seven or more factors. This is partly a reflection of the increase in frequency of the two pathotypes mentioned above.

Table 4. Number of virulence factors in the wheat mildew population, 1997-2001.

Number of virulence factors*	Frequency of isolates with each number of virulences (%)				
	1997	1998	1999	2000	2001
0	0	0	0	<1	**0**
1	0	0	0	0	**0**
2	0	0	0	0	**0**
3	0	0	<1	1	**0**
4	1	2	0	1	**2**
5	7	18	7	13	**8**
6	45	44	59	63	**47**
7	9	15	16	13	**15**
8	16	11	13	5	**15**
9	4	4	2	2	**4**
10	13	5	3	2	**7**
11	2	0	0	0	**0**
12	3	2	0	<1	**1**

* corresponding to the resistance factors in Table 1, with the exception of Pm3b (Chul), Pm17 (Amigo), MlSs (Soissons) and MlSh (Shamrock).

Infection of winter wheat cultivars

The specific resistance of 84% of the winter wheat area grown is matched by 98% or more of mildew isolates (Table 5).

Table 5. Proportion of mildew isolates able to infect winter wheat cultivars in HGCA Recommended List trials in 2001 (2002 RL cultivars in **bold**, 1-9 disease resistance ratings in brackets).

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Biscay (5)	100	**Solstice (5)**	100
Charger (8)	100	Storm (4)	100
Chatsworth (6)	100	Phlebas (7)	99
Claire (4)	100	**Access (7)**	98
Consort (7)	100	**Buchan (7)**	98
Deben (6)	100	**Equinox (5)**	98
Fender (7)	100	**Madrigal (6)**	98
Hereward (5)	100	**Napier (7)**	98
Macro (7)	100	**Savannah (7)**	98
Malacca (7)	100	**Tanker (6)**	98
Option (4)	100	**Soissons (8)**	82
Rialto (6)	100	**Shamrock (6)**	16
Riband (7)	100	**Xi 19 (8)**	10
Richmond (7)	100		

Whilst some of these cultivars are very susceptible in the field (*e.g.* Claire, rating 4), many have good partial resistance *e.g.* Charger (no specific resistance but rating of 8). Only Shamrock and Xi 19 have resistance matched by less than 20% of the mildew population. However, it is possible that Shamrock carries no effective partial resistance in addition to the unknown specific resistance and may become more susceptible as the corresponding specific virulence increases in frequency, as was the case in 2001.

Resistance genes in new cultivars

The resistance genes or factors found in new and existing cultivars are shown in Table 6. No new resistance genes or combinations were detected in 2001.

Table 6. Specific mildew resistance genes in winter wheat cultivars (2002 HGCA Recommended List cultivars in **bold**)

None	*Pm2,6*	*Pm2,Pm4b,Pm8*	*Mld?*
Charger	Abbot	**Access***	Aardvark
Chatsworth	Buster		
Eclipse	Macro	*Pm6,Pm8*	*MlTo*
Hereward	Reaper	Genghis	Spark
Rialto	Storm	**Madrigal**	
Solstice*		**Tanker**	*MlAx*
	Pm4b,Pm6		**Xi 19***
Pm2,Pm4b	Richmond	*Pm2,Pm4b(pm6,Pm8?)*	
Claire		**Option**	*MlSs*
	Pm2,4b,6		**Soissons**
Pm6?	**Biscay**	*Pm4b,Pm6,Pm8 (Pm2?)*	
Phlebas	**Consort**	**Buchan**	*MlSh*
	Deben	**Equinox**	**Shamrock**
	Fender	**Napier**	
	Malacca	Oxbow	
	Riband	**Savannah**	

* newly Recommended for 2002

REFERENCES

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 (2001). Seed Production No. 29, August 2001.

YELLOW RUST OF WHEAT

R.A. BAYLES, S.E. SLATER and F.G. HOPKINS

NIAB, Huntingdon Road, Cambridge CB3 0LE

2001 was a low yellow rust year. The pathotype virulent on Oxbow (WYV1,2,3,4,9,17,CV) was more common than in 2000, the year of its first detection. Field tests revealed that adult plants of Oxbow were very severely infected by this pathotype. The popular cultivar Consort was also susceptible, but was less severely infected.

INTRODUCTION

Following four years in which yellow rust was common, the incidence of the disease was exceptionally low in 2001. Due to the combination of a very wet autumn, more severe winter conditions than for several years and a wet spring, yellow rust appeared late in the season and was limited to restricted high risks areas only. In many cases, the samples collected consisted of only a single stripe taken from an otherwise healthy plant. The two most widely grown cultivars in 2001 were Claire and Consort, with yellow rust resistance ratings of 9 and 6 respectively (Table 1). More than 75% of the wheat area was made up of resistant or moderately resistant cultivars with ratings of 6 or above.

SEEDLING VIRULENCE TESTS OF ISOLATES COLLECTED IN 2001

Methods

65 samples of yellow rust were received in 2001, mostly from trial plots. Isolates were cultured from 60 samples, of which 31 were tested on the standard set of differential cultivars. The cultivars from which the isolates tested were collected are shown in Table 1. The samples not tested originated from susceptible cultivars with well-documented reactions to yellow rust.

Table 1. UK winter wheat cultivars for 2001, yellow rust resistance ratings (1-9), area grown and number of isolates tested (cultivars occupying <1% area not included unless isolate tested).

Cultivar	WYR factors	1-9 resistance rating *	% Area grown#	Number of isolates tested
Claire	Rx+APR	9	23.2	0
Consort	CV+	6 (9)	16.6	3
Malacca	Rx+APR	9	14.0	0
Option	R	9	6.6	0
Savannah	9,17	5	4.1	1
Hereward	CV+	7	3.9	3
Napier	6,9,17	4	3.5	0
Charger	?6+APR	9	2.4	0
Equinox	6,9,17	5	2.4	1
Tanker	9	7	2.3	2
Soissons	3	8	2.2	2
Shamrock	CV+	8	2.0	0
Deben	Rx+APR	9	1.4	0
Riband	13	7	1.0	0
Rialto	6,9	6	0.7	0
Madrigal	6,9,17	3	0.4	2
Biscay	9,17	5	0.2	3
Oxbow	CV+?9	2 (9)	0.2	4
Access	6,9,17	3	0.1	3
Buchan	9,17	3	0.1	1
Macro	R	7 (9)	0.1	2
Phlebas	6,9,17	8	0.1	3
Reaper	17	4	0.1	0
Apollo	9	3	-	1

* Rating shown is that for 2002. Previous rating shown in brackets if it differs by 2 points or more
# NIAB (2001)

All the isolates tested originated from trial plots, at locations in the east of England (Table 2).

Table 2. Locations from which the tested isolates were collected in 2001.

Location	Number of isolates
NIAB, Cambridge	17
Spalding, Lincs.	8
Headley Hall, Yorks.	3
Cockle Park, Northumberland	2
Rothwell, Lincs.	1

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

Table 3. Differential cultivars used in seedling virulence tests in 2001.

Differential cultivar	WYR factor	Gene designation
Core set		
Chinese 166	WYR 1	*Yr1*
Kalyansona	WYR 2	*Yr2*
Vilmorin 23	WYR 3	*Yr3 +*
Nord Desprez	WYR 3	*Yr3 +*
Hybrid 46	WYR 4	*Yr4*
Heines Peko	WYR 2,6	*Yr2, Yr6*
Heines Kolben	WYR 2,6	*Yr2, Yr6*
Lee	WYR 7	*Yr7*
Compair	WYR 8	*Yr8*
Kavkaz x 4 Federation	WYR 9	*Yr9*
Moro	WYR10	*Yr10*
Yr15/6*AvS	WYR15	*Yr15*
VPM 1	WYR17	*Yr17*
Carstens V	WYR CV	*Yr Carstens V*
Avocet 'R'	WYR A	*YrA*
Suwon 92 x Omar	WYR So	*Yr Suwon 92/Omar*
Strubes Dickkopf	WYR Sd	*Yr Strubes Dickkopf*
Spaldings Prolific	WYR Sp	*Yr Spaldings Prolific*
Additional cvs		
Buster	R	
Cadenza	R	
Consort	CV+	
Oxbow	CV+?9	

Reichersberg 42 (WYR7, *Yr7+*) was omitted from the differential set used in 2001.

Results

Table 4 shows virulence frequencies for the 15 years from 1987 to 2001.Virulence frequencies should be interpreted with caution because of the non-random nature of sampling and the relatively small number of isolates tested in 2001.

Virulence for Oxbow (Brigadier x Consort) was first detected in 2000 and was found at an increased frequency in 2001. Previously Oxbow had been resistant to all isolates, and had been given a resistance rating of 9. Virulent isolates carried the new combination of virulence for WYR9,17 together with virulence for WYR CV. These isolates were also virulent on Consort, which is believed to possess the WYR CV resistance. In total, 19 Oxbow-virulent isolates have now been identified. Eight of these came from Oxbow itself, five from Consort (WYR CV+), three from Hereward (WYR CV+), two from Soissons (WYR3) and one from Apollo (WYR9).

Virulence for WYR1, WYR2 and WYR3 was again detected in all isolates tested. There was a slight decrease in the frequency of virulence for WYR4 in 2001 compared with the previous two years. The frequencies of virulence for WYR1, WYR2, WYR3 and WYR4 remain high despite the lack of selection from cultivars with the corresponding resistances; with the exception of Soissons (WYR3) no current commercial cultivar is known to carry any of these resistances.

Table 4. Frequency of virulence factors from 1987 to 2001.

Virulence for	87	88	89	90	91	92	93	94	95	96	97	98	99	00	01
WYR 1	87	68	62	85	91	88	89	65	90	97	100	99	99	100	100
WYR 2	100	100	100	100	100	100	98	100	99	97	100	99	99	100	100
WYR 3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYR 4	47	78	97	91	86	86	89	86	67	59	47	79	87	90	74
WYR 6	89	72	57	69	64	88	68	41	35	16	1	7	21	32	39
WYR 7	8	6	2	9	19	7	8	4	0	3	7	4	10	4	0
WYR 8	*	*	*	*	0	0	0	0	0	0	0	0	0	0	0
WYR 9	5	66	99	94	88	76	84	94	95	97	99	99	99	92	90
WYR 17									57	84	99	99	100	96	77
WYR CV								75	55	9	13	1	4	16	42
WYR A												84	91	88	90
WYR So												78	91	90	77
WYR Sd												100	98	100	84
WYR Sp												0	0	0	0
Parade							3	0	0	0	0	0	0	0	0
Cadenza															0
Consort															36
Oxbow														16	32
No. of isolates	52	71	156	67	42	77	63	49	83	32	138	94	97	50	31

Virulence for WYR7 was not detected in 2001 although it has been present at low levels in the population for many years. The survey again failed to detect virulence for WYR8; there is currently no known selection for WYR7 or WYR8 in the UK.

Virulence for WYR6 has varied widely over the past ten years, generally reflecting the exploitation of this resistance in commercial cultivars. Virulence for both WYR9 and WYR17 remained high. These two resistances are currently present in nearly all high risk commercial cultivars i.e. those with yellow rust resistance ratings below 6.

Virulence remained high for WYR A, WYR So and WYR Sd, indicating that these resistances would be ineffective if used in the UK. Again, no virulence was detected for WYR Sp, Buster or Parade.

Table 5 compares pathotype frequencies in 2001 with those in 2000. In 2000, 86% of the isolates tested were of one of three pathotypes. Of these, WYV1,2,3,4,9,17, the most common pathotype in 2000, was not detected in 2001. WYV1,2,3,4,6,9,17, was found at similar levels in both years and WYV1,2,3,4,9,17,CV, the Oxbow-virulent pathotype, increased in frequency in 2001. The other pathotypes identified in 2001 were represented by only one or two isolates each. These included two pathotypes, WYV1,2,3,4,17,CV and WYV1,2,3,9,17,CV, that have not previously been detected by the UKCPVS. The identification of these pathotypes requires confirmation.

Table 5. Pathotype frequencies (%) in 2001 compared with 2000

	frequency %	
Pathotype*	2000	2001
1,2,3,4,9,17	46	
1,2,3,4,6,9,17	24	29
1,2,3,4,9,17,CV	16	32
1,2,3		3
1,2,3,4		3
1,2,3,4,17,CV		3
1,2,3,4,7,9,17	2	
1,2,3,4,9		6
1,2,3,6	2	
1,2,3,6,7	2	
1,2,3,6,9		3
1,2,3,6,9,17	4	6 -
1,2,3,9		3
1,2,3,9,17	4	3
1,2,3,9,17,CV		6

* Includes virulence for the first 14 differentials listed in Table 3 only, as being of most relevance to the UK.

FURTHER TESTS OF ISOLATES FROM 2000 AND EARLIER SURVEYS

2001 was the first year in which isolates identified as virulent on Oxbow in seedling tests could be tested on adult plants. A number of isolates collected during the 2000 survey were selected for adult plant tests in 2001. These included six Oxbow virulent isolates (WYV1,2,3,4,9,17,CV) listed in Table 6 and a control isolate WYV1,2,3,4,6,9,17. Yellow rust did not establish well in polythene tunnels in 2001; the epidemic was very slow to build up and infection levels were low except on the most susceptible cultivars. For this reason, the results are not presented here. However, it was clear that Oxbow was highly susceptible as an adult plant to isolates that had been identified as virulent in seedling tests.

Table 6. Oxbow-virulent isolates selected for adult plant tests in 2001

Isolate code	Location	Cultivar	Virulence
00/40	Cambs	Oxbow	1,2,3,4,9,17,CV
00/41	Lincs	Oxbow	1,2,3,4,9,17,CV
00/47	Norfolk	Oxbow	1,2,3,4,9,17,CV
00/55	Lincs	Oxbow	1,2,3,4,9,17,CV
00/46	Norfolk	Consort	1,2,3,4,9,17,CV
00/42	Lincs	Hereward	1,2,3,4,9,17,CV
98/96	Lincs	Madrigal	1,2,3,4,6,9,17

One of the Oxbow virulent isolates (00/41) and the control isolate (98/96) were tested in adult plant field nurseries (Table 7). As expected from seedling test results, cultivars possessing WYR9,17 were susceptible to 00/41, whereas those possessing WYR6,9,17 were not. Oxbow itself was highly susceptible to 00/41 and appears to possess little background, or partial, resistance. Consort and Hereward, which are both believed to possess WYR CV together with other resistances, were also susceptible to 00/41. However, these two cultivars developed considerably less infection than Oxbow and clearly have better partial resistance. No yellow rust was detected on Shamrock, which is not unusual as the cultivar is a 'late-ruster' and often escapes infection. Differences in the partial resistance of the cultivars are reflected in their 1-9 resistance ratings. The results of this and other adult plant tests using 00/41 resulted in the lowering of Oxbow's resistance rating from its previous value of 9 to 2 and Consort's rating from 9 to 6. Isolates with virulence for Hereward had already been detected in 1991 and there was no indication that 00/41 showed any further increase in virulence for this cultivar.

Oxbow has now been withdrawn by its breeder on the grounds of its susceptibility, a move that should reduce the immediate risk of spread of the new pathotype. However, the resistance of several other cultivars at earlier stages of official trials has also been overcome by the Oxbow-virulent pathotype and some of these cultivars are highly susceptible. If these were to become commercialised, the virulent pathotype would rapidly become more widespread

The six cultivars listed from Chatsworth to XI19, maintained their resistance to all isolates at both seedling and adult plant stages. The four cultivars Charger to Deben maintained their adult plant resistance, although showing susceptibility to some isolates at the seedling stage. Macro, which previously had a resistance rating of 9, has shown slight susceptibility in adult plant tests elsewhere, accounting the fall in its rating from 9 to 7. However, since all these tests were performed using mixtures of isolates of different pathotypes, it is not possible to draw any conclusions about the identity of Macro's specific resistance, except that it is unlikely to be of the Oxbow type.

CONCLUSIONS

The yellow rust resistance of the UK wheat crop as a whole was probably in as good, or better, position in 2001 than at any time during the past 30 years and little change is expected for 2002. Only about 11% of the total wheat area was occupied by susceptible cultivars with ratings of 5 or below. These are cultivars that are at moderate to high risk from yellow rust infection and are likely to require fungicides to control the disease. The comparable figure for the yellow rust epidemic year of 1972 was nearer to 75% of the wheat area occupied by cultivars with ratings of 5 or below. Nearly 50% of the wheat area for 2001 consisted of cultivars rated 9 for yellow rust resistance.

This favourable position has been achieved by a combination of plant breeding and independent variety evaluation, underpinned by a national pathogen virulence survey. There is however still scope for improvement. 2001 was only a snapshot in time and the genetic composition of the host population is constantly changing in response to the requirements of end users and growers. Changes in the host population are the driving force for changes in the pathogen population. It is impossible to predict the durability of the resistance of current cultivars, nor to be certain of the diversity of resistance that exists between them. There is a real risk that a single adaptation in the pathogen could potentially overcome the resistance of several major cultivars.

REFERENCES

Bayles, R A and Stigwood, P L (2001). Yellow rust of wheat. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp 28-36.

NIAB (2001). Seed Production, Issue number 29, August 2001.

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 7. Results of adult plant tests in spreader beds. Values are percentage leaf area infected with yellow rust (mean of 3 assessments).

		Isolate	98/96	00/41
		source cv	Madrigal	Oxbow
		location	Lincs	Lincs
		seedling virulence	1,2,3,4,6,9,17	1,2,3,4,9,17,CV
Cultivar	**WYR**	**1-9 resistance rating***		
Biscay	9,17	5	3.0	8.5
Buchan	9,17	3	9.5	11.5
Savannah	9,17	5	4.7	4.0
Access	6,9,17	3	9.2	0.4
Equinox	6,9,17	5	9.5	0.4
Genghis	6,9,17	6	7.2	0.3
Madrigal	6,9,17	3	10.5	0.0
Napier	6,9,17	4	11.3	0.1
Phlebas	6,9,17	8	1.7	0.5
Hereward	CV+	7	0.0	2.5
Consort	CV+	6 (9)	0.0	5.1
Oxbow	CV+?9	2 (9)	0.1	13.8
Shamrock	CV+	8	0.0	0.0
Chatsworth	R	9	0.0	0.0
Fender	R	9	0.0	0.1
Option	R	9	0.0	0.0
Richmond	R	9	0.0	0.0
Solstice	R	9	0.0	0.0
XI19	R	9	0.0	0.0
Charger	?6+APR	9	0.0	0.0
Malacca	Rx+APR	9	0.0	0.0
Claire	Rx+APR	9	0.0	0.0
Deben	Rx+APR	9	0.0	0.1
Macro	R	7 (9)	0.0	0.0
Tanker	9	7	5.7	3.7
Storm	9?	7	0.0	2.9
Rialto	6,9	6	6.5	0.0
Riband	13	7	4.2	2.9
Brock	7,14	2	0.0	0.0
Soissons	3	8	0.0	0.2

* Rating shown is that for 2002 (or the most recent available). Previous rating shown in brackets if it differs by 2 points or more.

BROWN RUST OF WHEAT

E.R.L. JONES

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

Isolates cultured from samples of the highly resistant cvs Buchan, Paragon and Wallace carried virulence to several of the 'Thatcher' near isogenic lines. They included lines Lr15, Lr17, Lr21 and Lr28 which have previously shown high levels of resistance. Isolate WBRS-01-04, cultured from cv. Buchan, was virulent on seedlings of some lines which have previously been resistant, as well as on adult plants of line Lr37. This resistance gene is deployed widely in UK and European wheat cvs. In field tests current HGCA Recommended List cvs generally expressed high levels of resistance to the specific isolates to which they were exposed.

GLASSHOUSE SEEDLING TESTS WITH YEAR 2001 ISOLATES

Eighteen samples were collected from a range of 15 winter and spring wheat cvs (Table 1) in 2001. Some were from cvs which previously expressed high levels of resistance, notably the winter wheat cv. Buchan, sampled from a crop assessed as having disease levels of 5%, cv. Tanker, 0.1% infection but 20% in foci and also the spring wheat cvs Paragon and Wallace described as having quite severe infection. The geographic origins of the samples are given in Table 1.

Table 1. Geographic origins of year 2001 wheat brown rust samples

Location (county)	Cultivar
Cambridgeshire	Consort, Soissons, Fender, Buchan, Deben, Solstice
Lincolnshire	Solstice, Rialto, Soissons, Option, Consort, Deben, Storm
Suffolk	Paragon, Wallace, CSW 98/20
South Glamorgan	Tanker
Staffordshire	Deben

Isolates of *Puccinia recondita* cultured from seventeen of these were tested on three sets of wheat lines. 1) Differential cvs which comprise the standard WBR cvs (Table 2). 2) The core set (agreed amongst European leaf rust workers) of 'Thatcher' Near Isogenic Lines (NILs) carrying different Lr resistance factors (Table 3). 3) A number of potential new winter and spring wheat cvs (Table 4).

Table 2. * Standard WBR cvs used in tests with 2001 isolates

Cultivar	WBR-factor	Lr gene
Clement	1	26
Fundin	2	17b
Sappo	3	20
Halberd	4	20
Sterna	7	3

*The differential cvs Huntsman (WBR-5), Gamin (WBR-6), Ranger (WBR-8) and Avalon (WBR-9) were not included as their resistances are of the adult plant type.

Table 3. Differential set of 'Thatcher' near isogenic lines used to identify leaf rust virulence and their ranking for octal notation

Lr gene	Pedigree	Ranking for octal notation
1	Tc6/Centenario	1
2a	Tc6/Webster	2
2b	Tc6/Carina	3
2c	Tc6/Loros	4
3	Tc6/Democrat	5
9	Transfer/Tc6	6
11	Tc6/Hussar	7
15	Tc5/Kenya W1483	8
17	Klein Lucero/Tc6	9
19	Tc7/T4	10
21	Tc6/R.L.54'06	11
23	Lee 310/Tc6	12
24	Tc6/Agent	13
26	Tc6/ST-1.25	14
28	Tc6/C77.1	15
Tc	Thatcher	-

Table 4. Newly introduced and potential new winter and spring* wheat cvs included in tests with isolates from the 2001 survey

Carlton	Status	CPBT W 74
Richmond	*Ambient	CPBT W 76
Xi 19	*Alder	Brunel
Warlock	NSL WW 39	CPBT W 78
Scorpion	NSL WW 41	
Goodwood	NSL WW 37	

Plants were grown and inoculated under standard conditions and, following incubation in dew simulation chambers at 15°C for 16 h in the dark, were transferred to one 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).

RESULTS

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

Based on the reactions of the standard differential cvs, three virulence combinations were identified in the 2001 isolates. These are given in Table 5 where their frequencies are compared with those from previous years. WBV-1,2,7, which was at an increased frequency in year 2000, showed a further increase in 2001.

Table 5. Virulence combinations and their frequencies identified from year 2000 isolates compared with 1992-2001*

WBV	Frequency							
formula	1992	1993	1994	1995	1998	1999	2000	2001
0	0.06	0.04	0.30	0.22	0.18	0.50	0.18	0
1	0	0	0.03	0.11	0.05	0.18	0.09	0.06
2	0.12	0.09	0	0.22	0.37	0.23	0	0
7	0	0	0.03	0	0.02	0	0	0
1,2	0.76	0.75	0.58	0.34	0.33	0.09	0.04	0.29
1,3	0	0.02	0	0	0	0	0	0
1,7	0	0	0	0	0	0	0.09	0
1,2,7	0	0.04	0.06	0.11	0.05	0	0.52	0.65
1,2,3	0	0.06	0	0	0	0	0	0
1,2,3,4	0.06	0	0	0	0	0	0.04	0
1,3,4	0	0	0	0	0	0	0.04	0
Number of isolates tested	17	53	39	18	43	22	23	17

*Only 1 and 4 isolates were tested in 1996 and 1997, respectively and these data are excluded

The individual virulence factors combined in these pathotypes also showed increased frequency (Table 6) with virulence to cv. Clement (WBR-1) being carried by all the isolates. WBV-2, at a frequency of 0.94, reverted to its 1992 levels, whilst WBV-7, which was at a greatly increased frequency in year 2000 isolates was at a similar level in 2001.

Table 6. Virulence frequencies corresponding to differential cvs for years 1992-2001

		Frequency							
Cultivar	WBR factor	1992	1993	1994	1995	1998	1999	2000	2001
Clement	1	0.82	0.87	0.67	0.55	0.43	0.27	0.82	1.00
Fundin	2	0.94	0.83	0.64	0.67	0.75	0.32	0.60	0.94
Sappo	3	0.06	0.08	0	0	0	0	0.08	0
Halberd	4	0.06	0	0	0	0	0	0.04	0
Sterna	7	0	0.04	0.08	0.11	0.07	0	0.61	0.65
Armada	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of isolates tested		17	53	39	18	43	22	23	17

*Only 1 and 4 isolates were tested in 1996 and 1997 respectively and these data are excluded

Virulence frequencies in the 2001 isolates corresponding to each Thatcher-Lr backcross line are given in Table 7 where they are compared against the previous three years. The resistances of genes Lr1, Lr2a, Lr9, Lr19, Lr23 and Lr24 remained effective at one or both temperatures. With the exception of Lr11, virulence to the remainder was at an increased frequency. Of these, resistances conferred by Lr15, Lr17, Lr21 and Lr28 have previously been very effective in adult plant controlled environment tests and in the field, although virulence to all of them has previously been identified in seedlings. Line Lr17 has also been susceptible in controlled environment adult plant tests as has Lr15 whose temperature-sensitive resistance has also been overcome in the field. Nevertheless the number of isolates carrying virulence to one or more of these Lr lines has remained very small, so it is difficult to explain the increased frequency in the 2001 isolates as it is not thought that the currently grown cvs carry these resistance genes.

As a consequence of increased frequency of individual virulences in the 2001 isolates, virulence combinations were generally more complex than those identified previously. The most widely virulent, race 62734 found in 4 isolates, carries virulence to nine of the Thatcher-Lr lines. Three of these isolates were cultured from samples of the highly resistant cvs Buchan, Paragon and Wallace, and the fourth came from cv. Deben grown at the same site as the cv. Buchan sample. They carry virulence to lines Lr2b, Lr2c, Lr3, Lr11 and Lr26. In addition, however, they also combine virulence to Lr15, Lr17, Lr21 and Lr28. Virulence to each of these resistance genes has previously been at a very low frequency (Table 7). Virulence to these four genes was not confined to those four isolates as some of the other samples carried virulence to some, but not all, of the lines. One of these was classified as octal race 62114 identified in isolate WBRS-01-14 cultured from infected leaves sampled from a crop of cv. Tanker showing disease levels of 20% in foci. This race differs from octal race 62734 in lacking virulence to Lr3, Lr15 and Lr17.

Of the newly introduced cvs, Status and CPBT W78 were resistant to all isolates at both temperature regimes. The spring wheat cvs Alder and Ambient have a temperature-sensitive resistance which was effective against all the isolates at 10°C.

The remainder of the cvs expressed mixed reactions to several of the isolates making classification as susceptible or resistant difficult. Cultivars Richmond, Xi19, Warlock and Scorpion displayed similar responses to the isolates. They were generally resistant at 10°C but susceptible to some isolates at 25°C. The remaining cvs, namely Goodwood, NSL WW37, NSL WW39, NSL WW41, CPBT W74, Brunel and CPBT W76 were classified as resistant to several of the isolates, although some were susceptible at 25°C to some isolates. They were, however, susceptible under both temperature regimes to the complex octal races 62734 and 62134.

Table 7. Virulence frequencies corresponding to each Thatcher-Lr backcross line for years 1998-2001

Thatcher Line	Frequency			
(Lr gene)	1998	1999	2000	2001
1	0	0	0	0
2a	0	0	0	0
2b	0.17	0.22	0	0.47
2c	0.52	0.26	0.04	0.53
3	0.07	0	0.29	0.65
9	0	0	0	0
11	0.96	0.49	0.61	0.53
15	0.04	0	0.08	0.47
17	0.04	0	0.08	0.53
19	0	0	0	0
21	0.02	0	0	0.53
23	0	0	0	0
24	0	0	0	0
26	0.43	0.32	0.83	1.00
28	0.07	0	0	0.53
Tc	-	-	-	1.00
Number of isolates	43	22	23	17

Table 8. Races and their frequencies, based on the reactions of Thatcher-Lr backcross lines, identified from the 2001 isolates of *Puccinia recondita*

Race (octal)	Frequency
20000	0.12
20420	0.12
20620	0.12
20630	0.06
22000	0.06
60114	0.06
62104	0.06
62114	0.06
62134	0.06
62330	0.06
62734	0.22

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Winter and spring wheat cvs, including those on the HGCA Recommended Lists, potential new cvs, the standard differential cvs and cv. Thatcher backcross lines carrying different Lr resistance factors, were sown in each of two nurseries. The nurseries were inoculated with one or other of the following isolates:

WBRS-00-12 (*WBV-1,2,7)	ex cv. Rialto, Cambridgeshire
WBRS-00-25 (*WBV-1,7)	ex cv. Wallace, North Yorkshire

*Virulence factors identified in seedling tests.

Isolate WBRS-00-12 was the only one from the year 2000 tests to infect seedlings of a number of newly introduced and potential new cvs at 10°C and 25°C. It was also the only one to overcome the resistances of cvs Storm and Ashby under the high temperature regime, both cvs being resistant to all other isolates at both high and low temperatures.

Isolate WBRS-00-25 was cultured from infected leaves of a crop of the highly resistant cv. Wallace whose resistance it overcame at 25°C in controlled environment tests.

Results

High levels of disease were established on the susceptible check cv. Arina. Table 9 shows, where identified, the WBR resistance factors, the Lr genes, and the resistance type of the cvs tested. With the exception of the standard differential cvs postulation of the Lr genes is based on:

1) European ring tests between 1996 and 1999 and additional seedling tests at the Plant Breeding Institute, Cobbitty, Australia (Winzeler, Mésterhazy and Park *et al.*, 2000).

2) Association with stripe rust resistance (WYR-) factors (Bayles and Stigwood, 1999, 2000, 2001). Lr genes postulated in this way appear in parentheses within the table.

Cultivars responded similarly to the two isolates. Of the standard differential (WBR-) cvs Fundin (WBR-2), Huntsman (WBR-5) and Arina (susceptible check) were infected at high levels. Cultivar Fundin was classified as resistant to isolate WBRS-00-25 in seedling tests but had been susceptible at 10°C. Both isolates overcame the temperature-sensitive overall resistances of cvs Sterna (WBR-7) and Sabre (WBR-7) in seedling tests but infected them at only low levels in the field. Disease levels on cv. Chablis, which likewise carries WBR-7 were also low. Cultivar Sappo (WBR-3), whose resistance had been effective only at 10°C in seedling tests, was infected in the field.

The majority of the HGCA Recommended List and potential new spring and winter wheat cvs showed no symptoms of brown rust infection. Several of these are postulated as carrying Lr37. This gene confers a temperature-sensitive, adult plant type resistance which appears to be effective across Europe (Winzeler, Mésterhazy and Park *et al.*, 2000). Some cvs carrying Lr37, generally in combination with other Lr genes, were infected in field nurseries at NIAB, Cambridge (J. Clarkson, NIAB, pers. comm.), particularly by isolate WBRS-98-20. The disease levels on these cvs were, however, very low, although cv. Savannah, thought to combine Lr37 with Lr26, was more heavily infected. Cultivars Hereward, Charger and Rialto were resistant, although they have previously been susceptible to other isolates. They carry resistance genes Lr10 and Lr13 (+26 Rialto). Virulence to Lr10 appears to be common in Europe and resistance conferred by Lr13, which is of the adult plant type, appears to be generally ineffective on its own

It can, however, provide protection when combined with other genes. Of the cvs with disease ratings of 5 or lower, only cvs Imp and Solstice have been susceptible in IGER field nurseries. The others, cvs Shamrock, Consort and Riband, have been infected only at low levels. They have, however, been susceptible in NIAB field nurseries (Clarkson and Mann, 2001) as have some of the other cvs which were resistant in IGER nurseries in 2001.

The reactions of the Thatcher near isogenic lines (NILs) are given in Table 10. The isolates were differentiated by the reactions of the lines Lr13 (adult plant resistance) and Lr26, which were susceptible to isolate WBRS-00-25 but resistant to WBRS-00-12, although both were identified as carrying virulence to Lr26 in seedling tests. Both pathotypes infected Lr3 although the winter cvs Sterna and Sabre and the spring cv. Chablis, which carry Lr3, were resistant. Resistance conferred by Lr9, Lr19, Lr24 and Lr37 remained effective but the previously resistant line Lr28 was highly susceptible. The European virulence survey for leaf rust in wheat 1996-1999 (Mésterhazy *et al.*, 2000) showed the effectiveness of Lr28 to fluctuate between year and location. Virulence to Lr28 increased in frequency during this period and appeared to be more common in Eastern Europe. As stated previously, there was also an increase in the frequency of isolates identified as carrying this virulence in the 2001 survey, although none of the current cvs are thought to carry Lr28. Line Lr21 showed high levels of resistance prior to 2001 with only one isolate, WBRS-98-20, carrying virulence to it. It was susceptible to both isolates in 2001 field tests, although neither isolate was identified as carrying virulence to it in seedling tests. This suggests that the nurseries became contaminated with naturally occurring pathotypes carrying virulence to Lr21, which was at an increased frequency in the 2001 isolates. Previously Lr15 has been susceptible in field nurseries inoculated with pathotypes to which it has been classified as resistant in seedling tests. This was probably due to the effect of temperature on its interactions with the isolates as it had been resistant at the high temperature only. Lr15 was, however, seedling resistant at 10°C and 25°C to the isolates introduced into the 2001 nurseries but was susceptible in the field, again suggesting contamination with naturally occurring pathotypes. As stated previously, virulence to Lr15 was at an increased frequency in the 2001 isolates.

CONTROLLED ENVIRONMENT TESTS

Winter and spring wheat cvs, currently on the HGCA Recommended List or which have been newly introduced, and which have high levels of brown rust resistance, were grown in a spore-proofed glasshouse until full emergence of the flag leaf. The majority of cvs were also tested as seedlings, whilst the potential new cvs Warlock and Scorpion were tested as seedlings only. Seedlings were grown to the second leaf stage. Also included were cv. Thatcher backcross lines, Lr13 and Lr37. Both resistances are of the adult plant type, and Lr37 has remained effective in the field. These genes, particularly Lr37, are deployed in several currently grown cvs. Two replicates (adult plants) of each cv. were inoculated with one each of the following isolates:

WBRS-01-17	(WBV-1,2,7)	cv. Wallace, Suffolk
WBRS-01-04	(WBV-1,2,7)	cv. Buchan, Cambridgeshire
WBRS-01-16	(WBV-1,2,7)	cv. Paragon, Suffolk

All were identified as octal race 62734 in seedling tests with the core set of Thatcher Near Isogenic Lines.

Following inoculation plants were incubated in dew simulation chambers at 15°C for 16 h in darkness, and then transferred to either a low temperature regime (10°C and 12 h photoperiod) or a high temperature regime (25°C and 16 h photoperiod). Seedlings were inoculated with the same isolates under the same conditions as the adult plants.

Results (Table 11)

Adult plants were assessed on percentage flag leaf area infected and reaction type classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4). Seedlings were assessed on infection type on the first leaf on the same 0-4 scale. Cultivars are classified into groups on the basis of similarities in their interactions with the isolates.

Group 1: Cultivar Status was resistant at 10°C and 25°C.
Group 2: Within this group cvs were, as adult plants, resistant or infected at very low levels at 10°C, but susceptible at 25°C. Their temperature-sensitive resistances were also expressed in seedling tests with the exception of cv. Paragon which was susceptible at both temperatures.
Group 3: Cultivar Chatsworth was resistant at 10°C to all isolates but differed from Group 2 cvs in expressing resistance at 25°C to isolate WBRS-01-04. It was seedling susceptible to all isolates as was cv. Savannah, thought to carry genes Lr26 and Lr37. Virulence to Lr26 is carried by the isolates whilst resistance conferred by Lr37 is effective only at the later growth stages.
Group 4: The overall resistances of the cvs was effective in previous years. They were, however, susceptible in seedling tests to isolate WBRS-01-04, cultured from cv. Buchan, a member of this group. This isolate failed to infect cv. Napier at 25°C as an adult plant. This was the only cv. within this group tested as an adult plant. It carries gene Lr10 in addition to genes Lr26 and Lr37 postulated to be carried by cv. Buchan.
Group 5: Cultivars Tanker (Lr26+) and Storm were susceptible as adult plants to isolates WBRS-01-17 and WBRS-01-04, although Tanker expressed a mixed, mainly resistant reaction in seedling tests to WBRS-01-17.
Group 6: Adult plant resistance conferred by gene Lr13 was overcome by isolates WBRS-01-17 and WBRS-01-04 but remained effective at 25°C to WBRS-01-16. Gene Lr13 has been deployed widely in European wheat cvs either on its own, when it is generally ineffective, or in combination with other Lr genes, where it continues to provide protection against many pathotypes, e.g. in the UK cvs Hereward and Charger (Lr10 + Lr13).
Group 7: Adult plant resistance conferred by gene Lr37 has been effective in the past to all but one isolate, WBRS-98-20, in controlled environment tests and to all isolates in field tests at IGER. It also appears to be effective, under field conditions, across Europe (Winzeler, Mésterhazy and Park *et al.*, 2000). It was, however, susceptible to isolate WBRS-01-04 in 2001 controlled environment tests, having been resistant to the other isolates at 25°C. This gene appears to have been introduced into several European cvs and is postulated to be carried, usually in combination with other Lr genes, in several UK cvs.

Virulence identified in controlled environment tests is not always confirmed in the field. Isolate WBRS-98-20, for example, was virulent on line Lr37 in controlled climate tests but failed to infect it in subsequent field tests, although in field nurseries at NIAB, Cambridge (Clarkson and Mann, 2001), it has infected a number of cvs postulated as carrying Lr37 at slightly higher levels than other isolates in these tests. Should virulence to Lr37 be confirmed in the field, then several of the currently grown wheat cvs will be at risk.

ACKNOWLEDGEMENTS

I am grateful to Dr Tim Carver (IGER) for his comments on this report. I thank Mr Warren Hutton (NIAB, Cambridge) for provision of seed of R.L. cvs.

REFERENCES

Winzeler, M., Mésterhazy, A., Park, R. *et al.* (2000). Resistance of European winter wheat germplasm to leaf rust. *Agronomie* **20,** 783-792.

Mésterhazy, A.*et al.* (2000). European virulence survey for leaf rust in wheat. *Agronomie* **20,** 793-804.

Bayles, R.A. and Stigwood, P.L. (1999). Yellow rust of wheat. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp.27-32.

Bayles, R.A. and Stigwood, P.L. (2000). Yellow rust of wheat. *UK Cereal Pathogen Virulence Survey 1999 Annual Report*, pp. 29-36.

Bayles, R.A. and Stigwood, P.L. (2001). Yellow rust of wheat. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp. 28-36.

Clarkson, R.D.S. and Mann, S.J. (2001). Brown rust of wheat: NIAB Adult Plant Tests. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp. 47-49.

Table 9. †Percentage infection of spring and winter wheat cvs to specific isolates of *Puccinia recondita* in field isolation nurseries in 2001

Isolate/Cultivar [1-9 rating]	WBR-	Postulated Lr genes	Resistance type	WBRS-00-12 (WBV-1,2,7)	WBRS-00-25 (WBV-1,7)
Clement	1	26	OR	2	0.1
Fundin	2	17b	OR*	25	25
Norman	2+		OR*	3 MS	0.3
Hobbit	2+		OR*	2	0.4
Sappo	3	20	OR*	6	5
Halberd	4	20	OR*	Trace	Trace
Huntsman	5	13	APR	32	28
Arina	(susc. check)	13 ?		43	60
Gamin	6		APR	0	Trace
Ranger	8		APR	0	0
Avalon	9		APR*	Trace	0.2
Sterna	7	3	OR*	0.1	Trace
Sabre	7	3	OR*	0.5	Trace
Chablis [6]	7	3	OR*	2	2
Shiraz [9]	7+	3+	Seed+APR*	0	0
Tanker [8]		(26+)	OR	0	0
Savannah [9]		(26+37)	OR	0	Trace
Buchan [9]		(26+37)	OR*	0	0
Biscay [9]		(26+37)	OR	0	0
Genghis		10(+26+37)	OR*	0	0
Madrigal [9]		(10+26+37)	OR	0	0
Equinox [9]		(10+26+37)	OR	0	0
Napier [9]		(10+26+37)	OR*	Trace	Trace
Phlebas		(10+26+37)	OR	0	0
Access [9]		(10+26+37)	OR	0	0
Oxbow			OR	0	0
Macro [9]			OR	0.1	0
Status [9]			OR	0	Trace
Richmond [9]			OR*	0	0
Xi 19 [8]			OR*	Trace R	Trace R
Chatsworth [9]			*	0	0
Alder [8]			OR*	0	0
Ambient [8]			OR*	0	0
Ashby [8]			OR*	0	Trace
Morph [8]			*	0	0
Wallace [8]			*	0	0
Option [7]			*	0	0
Deben [7]			*	0	0
Fender		37 +	*	0	0
Malacca [8]		10+13	APR	0	0
Hereward [8]		10+13	Seed+APR*	0	0
Charger [6]		10+13+26	Seed+APR*	0	0
Rialto	1+		Seed+APR*	0	Trace
Shamrock [5]			APR	0	Trace
Consort [5]			APR	0	0
Imp [5]			APR*	1	1
Riband [3]			*	1	0.4
Solstice [5]			*	27	28

†Mean of 3 replicates, 2 assessment dates. All reaction types susceptible unless stated. R = resistant
APR = adult plant resistance; OR = overall resistance; * temperature sensitive resistance.
Seed = effective seedling resistance against some pathotypes.
( ) postulated Lr genes based on links to resistances for stripe rust. [ ] Resistance rating: 1 = susceptible; 9 = resistant

Table 10. †Percentage infection of Thatcher-Lr backcross lines to specific isolates of *Puccinia recondita* in field isolation nurseries in 2001

Isolate Lr gene	Resistance type	WBRS-00-12 (WBV-1,2,7)	WBRS-00-25 (WBV-1,7)
1	OR*	0.3	0.5
2a	OR*	3	2
2b	OR*	10	4
2c	OR*	23	18
3	OR*	18	13
9	OR*	0	0
11	OR*	23	23
13	APR*	4 MR	18
14a	OR*	12	28
15	OR*	14	17
17	OR*/APR	2 R	7 MR
19	OR	0	0
20	OR*	0	0.2
21	OR	6	13
23	OR*	0.5	Trace
24	OR	0	0
26	OR	3	25
28	OR*	19	33
37	APR*	0.3 MR	0.5

†Mean of 3 replicates, 2 assessment dates.
All reaction types susceptible unless stated.
MR = mixed resistant; R = resistant
When more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response.
APR = adult plant resistance; OR = overall resistance
* = temperature-sensitive resistance

Table 11. Percentage area of *flag leaf infected and †reactions of winter and spring wheats to specific isolates of leaf rust at 10°C and 25°C

Cultivar	Group	WBRS-01-17 ▪(WBV-1,2,7)			WBRS-01-04 ▪(WBV-1,2,7)			WBRS-01-16 ▪(WBV-1,2,7)		
		Adult Plant		Seedling	Adult Plant		Seedling	Adult Plant		Seedling
		10°C	25°C	10/25°C	10°C	25°C	10/25°C	10°C	25°C	10/25°C
Status	1	0	0	R/R	0	0	R/R	0	0	R/R
Claire	2	8MR	13S		10MR	10S	MR/S	TraceS	10S	
Shiraz		0	23S	R/S	0	25S	R/S	0	23S	MR/MS
Wallace		5MR	23S	MR/S	10R	35S	R/S	13MR	25S	MR/S
Alder		1S	35S	MR/S	0	35S	R/S	1S	30S	MR/S
Ashby		2S	38S	MR/MS	TraceS	28S	MR/S	2S	30S	R/MS
Ambient		10MR	40S	MR/S	5R	33S	MR/S	8MR	25S	MR/S
Richmond		1S	18MS	MR/S	0.1S	20MS	MR/S	TraceS	10MS	MR/S
Xi 19		25R	40S	MR/S	20R	35S	MR/S	18R	20S	MR/S
Scorpion				R/MS			R/S			R/S
Warlock				MR/MS			R/S			MR/S
Paragon		20MR	35S	S/S	8R	23S	S/S	10MR	30S	S/S
Chatsworth	3	10R	18MS	S/MS	25R	20MR	MS/S	15R	9MS	MS/MS
Savannah				MS/MS			MS/MS			MS/MS
Napier	4	5S	10MR	MR/R	8S	18MR	MS/S	0	TraceS	R/R
Madrigal				MR/MR			MS/S			R/R
Equinox				MR/MR			MS/S			R/R
Brunel				MR/MR			MS/S			R/R
Buchan				MR/MR			MS/MS			MR/R
Biscay				MS/MS			MS/MS			MR/MR
Tanker	5	10S	23S	MR/MR	23S	35S	MS/MS	TraceS	1S	MR/MR
Storm		12S	15MS		30S	30S		13MR	24MR	
Lr13	6	25S	30MS		23S	33MS		40S	38MR	
Lr37	7	35MR	33S		16MS	28S		25MR	40S	

*Mean of 2 replicates.
†reaction types assessed on a 0-4 scale. Resistant (R: 0-2); Susceptible (S: 3-4)
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
▪virulence factors identified in seedling tests.

BROWN RUST OF WHEAT: NIAB ADULT PLANT TESTS

J.D.S. CLARKSON

NIAB, Huntingdon Road, Cambridge CB3 0LE

INTRODUCTION & METHODS

Four outdoor "spreader beds" of winter and spring wheat RL (and NL2) cultivars were each inoculated with an individual isolate of brown rust (*Puccinia triticina* Erikss.), as part of the Recommended List testing programme funded by HGCA. Further beds of NL1 cultivars of winter and spring wheat were inoculated with a mixture of the four individual isolates for testing of resistance/susceptibility to brown rust. A number of historic cultivars of known resistance were also included in the tests.

Methods employed were similar to those of previous years. Isolates were selected on the basis of possession of common virulence combinations in the current brown rust population (Jones 1999, 2000, 2001) and are shown in Table 1. The results for wheat cultivars in RL trials, expressed as the mean percentage leaf area infected over four assessment dates, are given in Table 2.

Table 1 Brown rust isolates used in outdoor tests, NIAB Cambridge, 2001

Isolate number	Probable virulence factors	Source of isolate
WBRS-98-20	WBV-1,2,6,7	cv Chablis, Cambs., 1998
WBRS-99-10	WBV-1,2,6	cv Rialto, Cambs., 1999
WBRS-99-11	WBV-2,6	cv Riband, Cambs., 1999
WBRS-99-8	WBV-6	cv Hereward, Cambs., 1999

RESULTS & DISCUSSION

Infection was successfully established in the plots, as indicated by the levels of brown rust on the susceptible cultivars such as Riband, Soissons and Imp (Table 2). Some resistant (1-9 resistance rating of 8 or 9) winter cultivars were slightly susceptible to one or more isolates, particularly WBRS-98-20 and WBRS-99-8; Savannah was slightly susceptible to all four isolates. Rialto (rating 4) showed lower than expected levels of infection: a trend that has been observed in recent years. Isolate WBRS-99-8 produced low levels of infection on all the spring cultivars with rating 8.

The majority of winter and spring cultivars, including the newer cultivars, are moderately resistant (rating 6 or 7) or resistant (rating 8 or 9) to brown rust, although the newly Recommended winter cultivar Solstice is susceptible. In winter cultivars, this resistance is mainly conferred by the genes *Lr26* + *Lr37*, with or without the addition of *Lr10*. *Lr37* is expressed as Adult Plant Resistance (APR) and is therefore important in conferring resistance to these cultivars. *Lr26* and *Lr37* were found to be present in 22% and 20% of UK wheat cultivars respectively (Singh *et al*, 2001) (not surprisingly in view of the close linkage with the yellow rust resistance genes *Yr9* and *Yr17* respectively). This resistance combination appears to remain effective at present, although occasional isolates have been obtained from such cultivars. For instance, a 2001 isolate from cv. Buchan, which contains *Lr26* + *Lr37*, was able to infect seedlings and adult plants of some *Lr26* + *Lr37* cultivars and the *Lr37* differential cultivar in Controlled Environment tests at both 10^0C and 25^0C (Jones, 2002). However, further tests are essential to ascertain whether this isolate can break down the resistance in the field, particularly as *Lr37* is expressed as APR. Any increase in virulence for *Lr26* + *Lr37* would have serious consequences for the current resistant winter cultivars; the latter must be closely observed for signs of infection.

Resistance conferred by *Lr13*, which is the most commonly detected gene in UK wheat cultivars (Singh *et al*, 2001), has been ineffective for some years now, as indicated by the moderate to high levels of infection on varieties such as Riband and the "historic" cultivars *e.g.* Maris Huntsman and Slejpner. This situation is mirrored in many parts of Europe (Mesterhazy *et al*, 2000).

Increasing virulence for *Lr3a* in recent years has resulted in increasing infection levels on the spring cultivar Chablis, although Shiraz (*Lr3a* + *?Lr23*) remains resistant.

ACKNOWLEDGEMENT

I thank Mr Elwyn Jones, IGER, Aberystwyth, for provision of brown rust isolates.

REFERENCES

Jones E R L (1999). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp 34-42.

Jones E R L (2000). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 1999 Annual Report*, pp 37-44.

Jones E R L (2001). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp 37-46.

Jones E R L (2002). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 2001 Annual Report*, pp 36-47.

Mesterhazy A, Bartos P, Goyeau H, Niks RE, Csosz M *et al* (2000). European virulence survey for leaf rust in wheat. *Agronomie* **20**, 793-804.

Singh D, Park RF & McIntosh RA (2001). Postulation of leaf (brown) rust resistance genes in 70 wheat cultivars grown in the United Kingdom. *Euphytica* **120**, 205-218.

Table 2. Mean % infection of winter & spring wheat cultivars by brown rust isolates in NIAB field tests, 2001

	VARIETY	1-9 RATING*	PROBABLE *Lr* GENES	ISOLATE				
				WBRS-98-20	WBRS-99-10	WBRS-99-11	WBRS-99-8	MIXTURE#
WW	**ACCESS**	9	*(10), 26, 37*	0.8	0	0	0	x
	BISCAY	9	*26, 37*	0	0	0	0	x
	BUCHAN	9	*26, 37*	0.2	0.5	0	0	x
	CHATSWORTH	9		0	0	0	0.1	x
	CLAIRE	9		0	0	0	0	x
	EQUINOX	9	*10, 26, 37*	0	0	0	0	x
	GENGHIS	9	*10, 26, 37*	1.3	0	0	0	x
	MACRO	9		0	0	0	0	x
	MADRIGAL	9	*10, 26, 37*	0	0.1	0	0	x
	NAPIER	9	*10, 26, 37*	0.3	0	0	0	x
	OXBOW	9	*26, 37*	0.4	0	0	0	x
	PHLEBAS	9	*(10), 26, 37*	0	0	0	0	x
	RICHMOND	9		0.1	0	0	0	x
	SAVANNAH	9	*26, 37*	4.5	2.5	0.1	3.3	x
	FENDER	8		0	0	0.1	0.6	x
	HEREWARD	8	*(10), 13, (APR)*	0.9	0	0	1.6	x
	MALACCA	8	*37 +*	0	0	0.1	0	x
	STORM	8	*26, 37*	1.3	0	0	6.7	x
	TANKER	8	*26 +*	0.4	0.3	0	7.7	x
	XI19	8		0	0	0	1.3	x
	DEBEN	7		1.9	1.0	0	6.2	x
	OPTION	7		5.8	3.0	1.3	6.7	x
	CHARGER	6	*10, 13*	0	0	0	10.9	x
	CONSORT	5	*10, 13*	0	0.6	2.9	8.4	5.6
	SHAMROCK	5		0	0	0.6	6.9	x
	SOLSTICE	5		10.3	10.6	10.8	10.9	x
	RIALTO	4	*10, 13, 26*	4.9	0.9	0.1	6.1	5.7
	RIBAND	3	*13, 17b*	33.8	13.8	7.1	11.5	30.0
	SOISSONS	2	*0*	36.3	9.9	5.4	17.5	38.4
	AVALON		*(APR)*	3.4	0.1	1.8	15.3	x
	HAVEN		*10, 13, 26*	1.4	0.3	0	6.3	x
	M HUNTSMAN		*13*	14.1	9.5	15.6	13.1	x
	MERCIA		*10, 13, (APR)*	9.7	7.9	15.6	11.6	x
	PASTICHE		*13, (APR)*	10.6	5.7	2.5	7.7	x
	SLEJPNER		*13, 26*	27.5	4.2	3.8	6.4	x
	VIRTUE		*13, (APR)*	2.6	0.0	4.6	11.8	x
SW	**PARAGON**	9		0	0	0	0	0
	SHIRAZ	9	*3a, (23)*	0	0	0	0	x
	STATUS	9		0	0	0	0	x
	ALDER	8		0	0	0	10.0	x
	AMBIENT	8		0	0	0.5	6.0	x
	ASHBY	8		0	0	2.5	2.5	x
	MORPH	8		7.5	0	0	3.5	x
	WALLACE	8		0	0	0	2.5	x
	CHABLIS	6	*3a*	20.0	15.0	8.5	20.0	22.5
	IMP	5		13.5	0	9.0	16.0	17.5
	ALEXANDRIA		*0*	37.5	11.0	15.0	30.0	25.0

Results are means of 4 assessments. x not tested.

* 1-9 scale (1 = susceptible; 9 = resistant). HGCA Recommended List **2002** varieties in **bold** type.

\# Mixture of 98-20, 99-10, 99-11, 99-8.

to these cultivars. *Lr26* and *Lr37* were found to be present in 22% and 20% of UK wheat cultivars respectively (Singh *et al*, 2001) (not surprisingly in view of the close linkage with the yellow rust resistance genes *Yr9* and *Yr17* respectively). This resistance combination appears to remain effective at present, although occasional isolates have been obtained from such cultivars. For instance, a 2001 isolate from cv. Buchan, which contains *Lr26* + *Lr37*, was able to infect seedlings and adult plants of some *Lr26* + *Lr37* cultivars and the *Lr37* differential cultivar in Controlled Environment tests at both 10^0C and 25^0C (Jones, 2002). However, further tests are essential to ascertain whether this isolate can break down the resistance in the field, particularly as *Lr37* is expressed as APR. Any increase in virulence for *Lr26* + *Lr37* would have serious consequences for the current resistant winter cultivars; the latter must be closely observed for signs of infection.

Resistance conferred by *Lr13*, which is the most commonly detected gene in UK wheat cultivars (Singh *et al*, 2001), has been ineffective for some years now, as indicated by the moderate to high levels of infection on varieties such as Riband and the "historic" cultivars *e.g.* Maris Huntsman and Slejpner. This situation is mirrored in many parts of Europe (Mesterhazy *et al*, 2000).

Increasing virulence for *Lr3a* in recent years has resulted in increasing infection levels on the spring cultivar Chablis, although Shiraz (*Lr3a* + *?Lr23*) remains resistant.

ACKNOWLEDGEMENT

I thank Mr Elwyn Jones, IGER, Aberystwyth, for provision of brown rust isolates.

REFERENCES

Jones E R L (1999). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp 34-42.

Jones E R L (2000). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 1999 Annual Report*, pp 37-44.

Jones E R L (2001). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp 37-46.

Jones E R L (2002). Brown rust of wheat. *UK Cereal Pathogen Virulence Survey 2001 Annual Report*, pp 36-47.

Mesterhazy A, Bartos P, Goyeau H, Niks RE, Csosz M *et al* (2000). European virulence survey for leaf rust in wheat. *Agronomie* **20**, 793-804.

Singh D, Park RF & McIntosh RA (2001). Postulation of leaf (brown) rust resistance genes in 70 wheat cultivars grown in the United Kingdom. *Euphytica* **120**, 205-218.

Table 2. Mean % infection of winter & spring wheat cultivars by brown rust isolates in NIAB field tests, 2001

	VARIETY	1-9 RATING*	PROBABLE *Lr* GENES	ISOLATE WBRS-98-20	WBRS-99-10	WBRS-99-11	WBRS-99-8	MIXTURE#
WW	**ACCESS**	**9**	*(10), 26, 37*	0.8	0	0	0	x
	BISCAY	**9**	*26, 37*	0	0	0	0	x
	BUCHAN	**9**	*26, 37*	0.2	0.5	0	0	x
	CHATSWORTH	9		0	0	0	0.1	x
	CLAIRE	**9**		0	0	0	0	x
	EQUINOX	**9**	*10, 26, 37*	0	0	0	0	x
	GENGHIS	9	*10, 26, 37*	1.3	0	0	0	x
	MACRO	9		0	0	0	0	x
	MADRIGAL	**9**	*10, 26, 37*	0	0.1	0	0	x
	NAPIER	**9**	*10, 26, 37*	0.3	0	0	0	x
	OXBOW	9	*26, 37*	0.4	0	0	0	x
	PHLEBAS	9	*(10), 26, 37*	0	0	0	0	x
	RICHMOND	9		0.1	0	0	0	x
	SAVANNAH	**9**	*26, 37*	4.5	2.5	0.1	3.3	x
	FENDER	8		0	0	0.1	0.6	x
	HEREWARD	**8**	*(10), 13, (APR)*	0.9	0	0	1.6	x
	MALACCA	**8**	*37 +*	0	0	0.1	0	x
	STORM	8	*26, 37*	1.3	0	0	6.7	x
	TANKER	**8**	*26 +*	0.4	0.3	0	7.7	x
	XI19	**8**		0	0	0	1.3	x
	DEBEN	**7**		1.9	1.0	0	6.2	x
	OPTION	**7**		5.8	3.0	1.3	6.7	x
	CHARGER	**6**	*10, 13*	0	0	0	10.9	x
	CONSORT	**5**	*10, 13*	0	0.6	2.9	8.4	5.6
	SHAMROCK	**5**		0	0	0.6	6.9	x
	SOLSTICE	**5**		10.3	10.6	10.8	10.9	x
	RIALTO	4	*10, 13, 26*	4.9	0.9	0.1	6.1	5.7
	RIBAND	**3**	*13, 17b*	33.8	13.8	7.1	11.5	30.0
	SOISSONS	**2**	*0*	36.3	9.9	5.4	17.5	38.4
	AVALON		*(APR)*	3.4	0.1	1.8	15.3	x
	HAVEN		*10, 13, 26*	1.4	0.3	0	6.3	x
	M HUNTSMAN		*13*	14.1	9.5	15.6	13.1	x
	MERCIA		*10, 13, (APR)*	9.7	7.9	15.6	11.6	x
	PASTICHE		*13, (APR)*	10.6	5.7	2.5	7.7	x
	SLEJPNER		*13, 26*	27.5	4.2	3.8	6.4	x
	VIRTUE		*13, (APR)*	2.6	0.0	4.6	11.8	x
SW	**PARAGON**	**9**		0	0	0	0	0
	SHIRAZ	**9**	*3a, (23)*	0	0	0	0	x
	STATUS	9		0	0	0	0	x
	ALDER	8		0	0	0	10.0	x
	AMBIENT	**8**		0	0	0.5	6.0	x
	ASHBY	**8**		0	0	2.5	2.5	x
	MORPH	**8**		7.5	0	0	3.5	x
	WALLACE	**8**		0	0	0	2.5	x
	CHABLIS	**6**	*3a*	20.0	15.0	8.5	20.0	22.5
	IMP	**5**		13.5	0	9.0	16.0	17.5
	ALEXANDRIA		*0*	37.5	11.0	15.0	30.0	25.0

Results are means of 4 assessments. x not tested.

* 1-9 scale (1 = susceptible; 9 = resistant). HGCA Recommended List **2002** varieties in **bold** type.

Mixture of 98-20, 99-10, 99-11, 99-8.

MILDEW OF BARLEY

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

NIAB, Huntingdon Road, Cambridge CB3 0LE

Virulence frequencies were similar to previous years. *Vra, Vg, V(CP), Va12, VLa, Va7* and *V(Ab)* were present at high levels. The frequency of *Vh* was lower in the air spora than in leaf samples. Levels of *Va6, Vk1* and *Va13* continued to decline. The barley mildew population continued to become more complex, with over 90% of isolates tested carrying eight or more virulence factors. However, the number of pathotypes identified continued to fall. The most commonly identified pathotype, *Vh,Vra,Vg,V(CP),VLa,Va12,Vk1,Va7,V(Ab),Va1,* was again detected in 10% of the samples tested. No new resistance factors or combinations were identified. Of the winter cultivars, only Leonie and Vanessa have effective specific resistance, but many cultivars have good non-specific resistance. *Mlo* remains the only effective specific resistance in spring cultivars. The number of isolates giving low levels of infection on the *mlo* differentials continued to rise slightly: close monitoring of this "partial virulence" situation is vital.

INTRODUCTION

Following a wet autumn, more severe frosts than for several years and a cool, wet spring, the incidence of mildew in the field was low in many areas in 2001. Mildew infection developed slowly on winter cultivars, although some susceptible spring cultivars were infected at an early stage. Only Headley Hall, Yorkshire, yielded good leaf samples from winter cultivars, but viable samples from spring trials were obtained from Yorkshire, Northumberland) and NIAB HQ, Cambridge. The air spora in Cambridge was sampled only in June.

METHODS

Virulence survey

91 samples were collected from infected leaves of trial plots in 2001, the majority from HGCA Recommended List trials. 24 samples failed to produce viable conidia but 135 single colony isolates were cultured from the remaining 67 samples. Isolates were collected from the locations shown in Table 1 and from the 10 spring and 29 winter cultivars shown in Table 2.

Table 1. Locations from which samples were collected in 2001.

	No. of isolates
Headley Hall, N. Yorks.	75
NIAB HQ, Cambridge	50
Cockle Park, Northumberland	10
Total	**135**

Table 2. Cultivars from which samples were collected in 2001.

Spring cultivars

	isolates		isolates		isolates
Chime	8	Spire	6	Riviera	4
Optic	8	Tavern	6	Chalice	2
County	6	Prisma	4	Adonis	1
Spike	6				

Winter cultivars

	isolates		isolates		isolates
Vanessa	8	Angela	2	Milena	2
Fanfare	6	Antonia	2	Muscat	2
Chamomile	5	Carat	2	Pict	2
Intro	5	Diamond	2	Regina	2
Avenue	4	Flute	2	Scylla	2
Heligan	4	Gleam	2	Siberia	2
Pastoral	4	Haka	2	Sumo	2
Pearl	4	Jackpot	2	Vertige	2
Manitou	3	Jewel	2	Whisper	2
Opal	3	Leonie	2		

Plants of the susceptible spring cultivar Golden Promise were exposed to the local air spora in Cambridge in June and 100 single colony isolates taken from the resulting infection were tested.

Isolates were tested for virulence on detached leaves of differential cultivars listed in Table 3.

Table 3. 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
Regina	*Mla7*	6b
Lotta	*Ml(Ab)*	6c
Triumph	*Mla7, Ml(Ab)*	6b, 6c
Tyra	*Mla1*	7
Roland	*Mla9*	8
Apex	*mlo*	9
Riviera	*mlo*	9
Digger	*Mla13*	10a
Ricardo	*Mla3*	11

The winter barley cultivars Vanessa, Leonie, Milena and Ludine and the spring cultivars County, Spike and Spire, which have unknown resistance, were also included in some tests.

Virulence for *mlo* cultivars

Isolates collected in 1998, 1999 and 2000 and described as "partially virulent" (Schwarzbach, 1998) to cultivars carrying *mlo* resistance were further tested on a range of cultivars.

RESULTS AND DISCUSSION

Virulence

The results of the 2001 survey are shown in Table 4.

Table 4. 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 2001.

Virulence gene	% Frequency of virulence factors			% Area of corresponding resistance #
	Leaf sample		Random samples of airborne spores	
	All data	Non-corresponding virulence *		
Vh	78	73	55	25
Vra	100	100	100	29
Vg	100	100	97	22
V(CP)	99	98	97	22
Va6	20	18	17	<1
VLa	91	91	99	0
Va12	99	98	100	25
Vk1	58	58	56	0
Va7	99	99	98	10
V(Ab)	93	93	98	22
Va1	67	63	68	3
Va9	28	27	28	0
vo	0	0	0	22
Va13	24	16	9	<1
Va3	2	2	0	0
No. of isols.	**135**		**100**	

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

NIAB (2001)

Virulence for *Vra* was again detected in all isolates tested, while *Vg, V(CP), Va12, Va7* and *V(Ab)* were present at very high levels. *VLa* was also present in over 90% of the isolates, although no currently grown cultivars are thought to carry the corresponding resistance. There was a large difference in the levels of *Vh* determined from isolates derived from leaf samples and from the air spora in June. As only 25% of the barley area selects for *Vh*, much of the airborne population is likely to have been generated by infections on cultivars lacking *Mlh*, particularly as populations in June may have been influenced by spring cultivars, none of which carry *Mlh*. The leaf samples were collected mainly from winter barley trials, in which a third of the cultivars in HGCA Recommended List trials are thought to carry *Mlh*.

Virulence for *Mlk1* was detected in just over half the isolates tested, despite no apparent selection for *Vk1* in the field. The area of cultivars carrying *Mla1* is small (3% of the barley area grown in 2001), but nevertheless the corresponding virulence was detected in over 60% of the isolates tested. However, the non-corresponding virulence frequency is slightly lower than the level derived from all leaf isolates, suggesting that *Va1* would decrease in the continued absence of selection. *Va9* also remains present in the population, detected in 28% of isolates in 2001, despite the absence of cultivars carrying *Mla9*. *Va6* was present in just under 20% of the isolates tested, although the area of cultivars selecting for this virulence is small, representing less than 1% of the barley area grown in 2001.

There was a large difference between the levels of *Va13* derived from all leaf isolates, non-corresponding data and air spora. The lower level of non-corresponding virulence suggests that *Va13* does not occur widely on hosts lacking *Mla13*, nor in the general air spora. The latter was probably derived from a mixed mildew population generated by commercial crops, less than 1% of which were represented by *Mla13* cultivars nationally in 2001.

Va3 was again detected in a few isolates, despite no known selection by current commercial cultivars. Virulence for *mlo* was not detected in 2001 and the *mlo* resistance remains effective in the field. However, some isolates gave limited infection on Apex and Riviera in differential tests. These isolates will be further examined for partial virulence to *mlo*.

Table 5. Virulence frequencies in barley mildew, 1993 to 2001.

Virulence	Virulence frequency (%) *								
gene	1993	1994	1995	1996	1997	1998	1999	2000	2001
Vh	78	79	70	78	68	61	58	50	68
Vra	100	99	100	100	100	100	100	100	100
Vg	96	95	95	96	95	97	97	97	99
V(CP)	92	88	90	90	93	94	95	96	98
Va6	35	31	34	30	25	31	26	23	19
VLa	22	25	31	56	58	72	89	88	95
Va12	72	67	71	70	73	76	87	88	99
Vk1	75	72	72	76	71	73	66	61	57
Va7	76	69	73	76	73	76	85	95	99
V(Ab)	76	74	67	62	52	53	71	79	95
Va1	18	23	27	38	36	45	64	65	67
Va9	29	34	33	37	33	32	25	29	28
Va13	38	43	37	41	39	25	19	11	17
Va3	1	<1	<1	<1	1	1	1	5	1
Number of isolates	628	539	552	428	551	743	629	689	235

* Mean of leaf samples and random samples of airborne spores for each year. Data from Slater & Clarkson (2001a).

Table 5 compares the virulence frequencies for 1993 to 2001. *Vra* has remained at 100% since 1994, while *Vg* and *V(CP)* remain near the maximum level. *VLa*, *Va12*, *Va7* and *V(Ab)* have all increased in frequency over the last few years. The increase in *Va12* in the last four years reflects the increase in the barley area sown with cultivars carrying *Mla12* (5% in 1997, 25% in 2001). However, although the frequency of *V(Ab)* has risen, the area of *Ml(Ab)* cultivars has remained around 20% since 1999; much of this is comprised of the spring cultivar Optic, which carries *Ml(Ab)* in addition to *Mla12*. *VLa* and *Va7* frequencies have continued to rise, despite a reduction in the selective area. The area of *Mla7* cultivars has dropped since 1999, with the decrease in popularity of the winter cultivar Regina. There are currently no cultivars in commerce known to carry *MlLa*.

Va6 has continued to decrease, following a reduction in the area of cultivars with the corresponding resistance. *Vk1*, stable in the early 1990s, has decreased since 1998; there have been no *Mlk1* cultivars grown commercially for 10 years. The last nine years have seen little change in the frequency of *Va9*, during which time there has been little or no selection for this virulence. *Vh* has also decreased throughout the last decade, but showed a rise in 2001. This may be due to the increase in the area of the winter cultivar Pearl (*Mlh,Mlra,Mlg*), now the most popular winter cultivar (32% of the winter barley area in 2001).

Virulence for *Mla13* showed a slight rise in 2001, despite little commercial selection for *Va13*. However, this increase may be the result of non-random sampling, since 12 isolates from *Mla13* cultivars in trials were tested in 2001, compared to none in 2000. The rise in frequency of *Va3* in 2000 may also have been due to sampling bias, as the frequency in 2001 was again only around 1%.

Complexity of isolates

The barley mildew population continues to become more complex, with over 90% of isolates carrying eight or more virulence factors, compared to 80% in 2000. Table 6 compares the number of virulence factors carried by isolates tested in 1993 - 2001.

Table 6. Comparison of the complexity of isolates collected from 1993 to 2001.

Number of	% Frequency of isolates with each number of virulences*								
virulence factors	1993	1994	1995	1996	1997	1998	1999	2000	2001
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	<1	0	<1	<1	0	0	0	0	0
3	<1	0	<1	1	0	<1	0	0	0
4	4	1	1	1	1	1	1	1	0
5	18	4	4	3	4	4	1	1	<1
6	34	10	11	7	11	10	8	6	0
7	27	24	19	14	17	15	10	8	5
8	10	25	28	22	23	22	21	21	17
9	4	16	20	24	21	18	18	26	29
10	1	12	10	16	16	20	25	24	29
11	<1	4	5	10	4	6	12	11	14
12	0	2	1	8	2	2	3	1	4
13	0	0	0	3	<1	<1	1	0	0
Total number of isolates	628	539	552	428	551	743	629	689	235

* includes all virulences listed in Table 2

The majority of isolates tested in 2001 carried nine or ten virulence factors, with very few isolates carrying less than seven factors. In contrast, 1993 isolates commonly carried only six or seven factors, with very few having more than eight virulence factors.

The commonest pathotype was again *Vh,Vra,Vg,V(CP),VLa,Va12,Vk1,Va7,V(Ab),Va1* (10% of the isolates tested in 2000 and 2001). 9% of the isolates tested in 2001 were identified as pathotype *Vh,Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1*.

There was a further reduction in the number of pathotypes identified, as shown in Table 7. The number of pathotypes, relative to the number of isolates tested, has halved since 1995. Although still only at a low level, the frequency of the commonest pathotype has doubled during this period, suggesting a trend towards a dominant pathotype in the population.

Table 7. Number of pathotypes identified, 1995-2001.

	Total number of isolates tested	Number of pathotypes	Ratio of number of pathotypes to number of isolates tested	Frequency of the commonest pathotype(%)
1995	552	298	0.54	3
1996	428	238	0.56	3
1997	551	277	0.50	4
1998	743	302	0.41	6
1999	629	202	0.32	8
2000	689	190	0.28	10
2001	235	61	0.26	10

Infection of barley cultivars

The majority of the winter barley cultivars currently in commercial use are potentially very susceptible to the bulk of the mildew population, as shown in Table 8. Heligan, Pastoral and Regina are the most susceptible cultivars with ratings of only 3. They have specific resistance matched by almost all the population (100%, 100% and 99% respectively) and have no effective non-specific resistance for protection in the field. However, although potentially at risk from a large proportion of the population, many of the cultivars have good non-specific field resistance, as shown by their high resistance rating. Pearl, currently the most popular winter cultivar, has specific resistance matched by 68% of the mildew population but is relatively resistant in the field (rating 8). Of the cultivars newly recommended for 2001, Avenue, Opal and Haka have specific resistance matched by much of the population (100%, 99% and 68% respectively) but have good non-specific field resistance (all rating 7). Sumo also has a rating of 7, but has unknown specific resistance which is probably matched by the bulk of the population (94% in 2000; not tested in 2001). Only Leonie of the newly recommended cultivars has good specific resistance, matched by only 8% of the pathogen population. Whether Leonie also carries effective non-specific resistance will only become apparent when the virulence corresponding to its specific resistance is widespread.

Most of the spring cultivars carry very effective specific resistance conferred by the *mlo* gene. Two of the three cultivars newly recommended for 2001 carry *mlo* resistance. *mlo* cultivars represented 46% of the spring barley and 22% of the total barley area in 2001. The third cultivar to be added to the 2001 HGCA Recommended List, County, has good non-specific resistance, although its specific resistance is matched by half the mildew population.

Table 8. Proportion of mildew isolates tested in 2001 able to infect barley cultivars in Recommended List trials (1-9 Resistance rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Avenue (7)	100	Angela (8)	68
Heligan (3)	100	Antonia (5)	68
Intro (6)	100	Haka (7)	68
Muscat (6)	100	Pearl (8)	68
Pastoral (3)	100	Scylla (7)	68
Pict (5)	100	Siberia (7)	68
Carat (7)	99	Whisper (7)	68
Chamomile (4)	99	Manitou (5)	28
Diamond (7)	99	Jackpot (7)	19
Fanfare (5)	99	Gleam (6)	17
Flute (8)	99	Leonie (8)	8
Jewel (6)	99	Milena (8)	8
Opal (7)	99	Vanessa (8)	8
Regina (3)	99		
Vertige (5)	99	Sumo (7)	?

Spring cultivars	Proportion (%)	Spring cultivars	Proportion (%)
Optic (6)	95	Chariot (9)	0
Prisma (4)	93	Chime (9)	0
County (8)	52	Decanter (9)	0
Tavern (7)	52	Harriot (9)	0
Spire (8)	14	Pewter (9)	0
Spike (8)	12	Riviera (9)	0
Adonis (9)	0	Saloon (9)	0
Cellar (9)	0	Static (9)	0
Chalice (9)	0		

Resistance factors in new cultivars

No new resistance factors or combinations were apparent in the new candidate cultivars in 2001 (see Table 9). Of the winter cultivars, only Milena carries resistance not matched by the majority of the pathotypes in the population. As all the isolates that infected Milena also infected Leonie and Vanessa, it seems likely that the three cultivars have common resistance. However, isolates which infected Leonie but not Vanessa were detected in 2000. It is uncertain, therefore, whether Milena carries the additional resistance of Vanessa or only the resistance observed in Leonie. The spring cultivars Spike and Spire carry *Mla13*, while the remaining new spring candidates, Adonis and Harriot, probably carry *mlo*.

Table 9. Resistance genes of barley cultivars (2002 Recommended List cultivars in **bold**)

None	*Mlh,Mlra,Mlg,Ml(CP),Mla6*	*Mla13*
Halcyon (W)	Gleam (W)	Pipkin (W)
Hanna (W)		Spike (S)
	Mla12	**Spire** (S)
Mlra	Flute (W)	
Avenue (W)	**Jewel** (W)	*mlo*
Heligan (W)		Annabell (S)
Intro (W)	*Mlra,Mla12*	Adonis (S)
Muscat (W)	**Carat (W)**	Barke (S)
Pict (W)	Diamond (W)	**Cellar** (S)
Pastoral (W)		Century (S)
	Mla7 (Mlra?)	**Chalice** (S)
Mlh,Mlra	**Regina** (W)	**Chariot** (S)
Angela (W)		Chime (S)
Haka (W)	*Mlh,Mlra,Mla7*	Dandy (S)
Siberia (W)	**Vertige** (W)	**Decanter** (S)
		Extract (S)
Mlh, Mlg	*Mla12,Ml(Ab)*	Harriot (S)
Antonia (W)	**Optic** (S)	Hart (S)
		Pewter (S)
Mlra,Mlg,Ml(CP)	*Mlg,Ml(CP),Mla12,Ml(Ab)*	Prestige (S)
Fanfare (W)	**Prisma** (S)	**Riviera** (S)
		Saloon (S)
Mlh,Mlra,Mlg,Ml(CP)	*Mla1(Ml(Ab),MlLa?),*	**Static** (S)
Opal (W)	**County** (S)	
Pearl (W)	**Tavern** (S)	Unknown
Scylla (W)		**Leonie** (W)
	Ml(Ab),Mla1	Milena (W)
Mla6 (Mlra?)	Delibes (S)	**Sumo** (W)
Jackpot (W)		**Vanessa** (W)

(W) winter cultivar (S) spring cultivar

Virulence for *mlo* cultivars

Despite the identification of isolates with low levels of partial virulence in both Europe (Schwarzbach, 1987) and the UK (Slater & Clarkson, 2001b), the *mlo* resistance remains extremely effective in the field. However, the number of isolates giving some infection on Apex and Riviera in differential tests in 2001 has risen slightly, as shown in Table 10. The level of partial virulence possessed by these isolates has yet to be determined, but further tests are in progress.

Further tests carried out with isolates collected in 1998 and 1999 confirmed the presence of partial virulence for *mlo*. Comparative tests with isolates from the Czech Republic have shown similar levels of partial virulence in both sets of isolates (Schwarzbach, Slater & Clarkson, 2002). As these isolates also possess virulence genes corresponding to resistance in other commonly grown cultivars in addition to *vo*, they have the capacity to reproduce on non-*mlo* hosts. Should isolates such as these become more common, they could pose a serious threat to the spring barley crop in the UK and Europe, almost half of which is represented by *mlo* cultivars.

Table 10. Proportion of isolates infecting Apex and Riviera in differential tests, 1996-2001 (as percentage of isolates tested)

Year	Apex	Riviera
1996	29	15
1997	24	13
1998	29	24
1999	27	23
2000	44	32
2001	48	34

REFERENCES

NIAB (2001). Seed Production No. 29 (August 2001).

Schwarzbach, E. (1987). Shifts to increased pathogenicity on *mlo* varieties. In: M. S. Wolfe and E. Limpert (eds.), Integrated Control of Cereal Mildews: Monitoring the Pathogen, pp5-7. Publ. Martinus Nijhoff, 1987.

Schwarzbach, E. (1998). The *mlo* based resistance of barley mildew and the response of mildew populations to the use of varieties with the *mlo* gene. *Czech Journal of Plant Breeding 34*, pp 3-10

Schwarzbach, E., Slater, S.E. and Clarkson, J.D.S. (2002). Occurrence of partially *mlo*-virulent isolates of barley powdery mildew in agricultural environments in Europe. *Cereal Rusts and Powdery Mildews Bulletin*: www.crpmb.org/2002/0208schwarzbach.

Slater, S.E. and Clarkson, J.D.S. (2001a). Mildew of barley. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp 50-59.

Slater, S.E. and Clarkson, J.D.S. (2001b). Reaction of spring barley cultivars carrying the *mlo* resistance to infection by powdery mildew isolates in the UK. *Cereal Rusts and Powdery Mildews Bulletin*: www.crpmb.org/2001/0724slater.

MILDEW OF BARLEY IN NORTHERN IRELAND

P.C. MERCER and A. RUDDOCK

Applied Plant Science Division, Department of Agriculture and Rural Development, New Forge Lane, Belfast BT9 5PX

Difficulties were again experienced in obtaining a large number of isolates and only 11 were obtained, all from spring barley. *Va3* continues at a relatively high frequency and *Va12* has shown an increase. Although there was no increase in virulence frequency of *vo*, isolates were obtained which were virulent on cultivars Atem and Apex; there is no indication of field breakdown.

INTRODUCTION

As in 1999 and 2000 (Mercer and Ruddock, 2000, 2001), there was again a problem in obtaining mildew isolates. This was also reflected in several barley trials where the application of fungicides had negligible effects on yield. Collection of isolates was further hampered because of movement restrictions due to Foot and Mouth Disease and those isolates that were obtained came from research centres. As can be seen from Table 1 there is now a complete predominance in *mlo* cultivars in spring barley, the most widely grown cereal crop. Whether this is the sole reason for the lack of mildew is not entirely clear, but it seems likely that it is an important contributory factor.

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 the virulence of isolates and their genetic designation is shown in Table 2.

Table 1. Percentage use of barley cultivars in N. Ireland (2000/01)

Spring cultivars *(resistance genes)*	**%**	**Winter cultivars** *(resistance genes)*	**%**
Riviera (*mlo*)	43	Regina (*Mlra, Mla12*)	57
Static (*mlo*)	30	Jewel (*Mla12*)	28
Dandy (*mlo*)	13	Pearl (*Mlh, Mlra, Mlg, Ml(CP)*)	21
Annabel (*mlo*)	10	Haka (*Mlh, Mlra*)	12
		Pastoral (*Mlra*)	3

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

Cultivar	Resistance gene	BMR group
Golden Promise	none	0
Weihenstephan 37/136	*Mlh*	la
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 + 6c
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. Results are generally very consistent with those of the previous season. *Va3* continues at a high level of frequency, considerably higher than in England, (Slater and Clarkson, this report), which is again surprising as no cultivars carrying the corresponding resistance gene are widely grown. The frequency of *Va12* was higher than in the previous season, possibly reflecting the popularity of winter barley cultivars carrying the corresponding resistance gene. Although it appears from Table 3 that there was no virulence on *mlo* differentials, if corresponding pathogenicity is added the value rises to 27% for *vo* and 9% for *Vla* + *vo*. However, as in previous years, this was not reflected in any breakdown in the field, indeed quite the contrary. Of the combined virulences, *Vla+V13* and *VLA, Vk+ Va7* showed large drops.

Complexity of isolates was estimated in 2000 and 2001 (Table 4) and shows a slightly higher level than that estimated in England (Slater and Clarkson, this report). This was generally due to the addition of *Va3*, *Va9* and *Va13*. The commonest pathotypes are shown in Table 5.

Table 3. Frequencies of virulence alleles from isolates collected from barley crops from 1990 to 2001

Virulence gene	BMV group	Frequency of virulence alleles										
		90	91	92	93	94	95	96	97	98#	00	01
Vh	1a	na	na	na	na	na	na	na	75	60	55	55
Vra	1b	na	na	na	na	na	na	na	83	77	65	na
Vg, V(CP)	2	43	64	39	43	77	50	52	67	60	86	82
Va6	3	41	54	36	47	56	26	41	58	41	52	13
VLa	4	27	57	25	47	42	44	33	75	79	87	82
Va12	5	46	54	31	67	74	61	80	58	52	52	88
Vk1	6a	na	na	na	na	na	na	na	83	75	87	64
Va7	6b	na	na	na	na	na	na	na	75	41	87	73
V(Ab)	6c	na	na	na	na	na	na	na	100*	73	75	75
Va1	7	20	14	14	40	22	41	7	100*	39	80	91
Va9	8	27	30	28	30	29	46	45	67	42	65	73
vo	9	na	na	na	na	na	na	na	8	9	12	0
Va13	10	14	46	25	27	37	19	38	50	29	50	45
Va3	11	na	na	na	na	na	na	na	17	5	50	64
Va6, VLa	3 + 4	67	39	36	30	50	22	33	67	41	41	36
VLa, Va12	4 + 5	27	50	47	30	53	24	33	67	31	71	75
VLa, Vk	4 + 6a	50	50	44	30	24	33	48	67	52	90	91
VLa + vo	4 + 9	0	0	0	0	0	4	0	0	2	16	0
VLa, Va13	4 + 10	na	na	3	0	11	6	35	25	3	43	0
Vk, Va7	6a + 6b	48	57	31	37	38	28	43	67	33	56	73
Va7, V(Ab)	6b + 6c	33	71	36	47	59	38	25	100*	50	80	75
VLa, Vk + Va7	4 + 6a + 6b	59	41	44	27	38	22	28	58	24	76	27

* only two isolates; # no mildew in 1999

Table 4. Complexity of isolates in 2000 and 2001

Number of virulence factors	2000	2001
0	0	0
1	0	0
2	0	0
3	0	0
4	7	0
5	3	0
6	3	0
7	3	18
8	13	18
9	3	0
10	7	9
11	13	9
12	23	37
13	17	0

Table 5. Commonest pathotypes 1997 – 2001

Pathotype	1997	1998	2000	2001
Vh, Vra, Vg, V(CP), VLa, Va12, Vk1, Va7, V(Ab), Va1, Va9, Va13, Va3*	0	0	7	27
Vh, Vra, Vg, V(CP), VLa, Va12, Vk1, Va7, V(Ab), Va1, Va6, Va9, Va13, Va3*	0	0	17	0
Vh, Vra, Vg, V(CP), Vla Va12, Vk1, Va7, V(Ab), Va1, Va6, Va9, Va13*	27	0	13	0
Vh, Vra, Vg, V(CP), VLa, Va12, Vk1, Va7, V(Ab), Va1, Va9*	0	2	0	0

*assumed, on previous evidence to be present in 2001 (differential cultivar failed to germinate in that year)

REFERENCES

Mercer, P.C. and Ruddock, A. (2000). Mildew of barley in Northern Ireland. *UK Cereal Pathogen Virulence Survey 1999 Annual Report,* p. 57.

Mercer, P.C. and Ruddock, A. (2001). Mildew of barley in Northern Ireland. *UK Cereal Pathogen Virulence Survey 2000 Annual Report,* pp. 60 - 62.

Slater, S.E. and Clarkson, J.D.S. (2002). Mildew of barley. *UK Cereal Pathogen Virulence Survey 2001 Annual Report,* pp. 51-59.

YELLOW RUST OF BARLEY

S.E. SLATER, R.A. BAYLES and F.G. HOPKINS

NIAB, Huntingdon Road, Cambridge, CB3 0LE

The incidence of yellow rust of barley was again negligible in 2001. Four samples were received, three from breeders lines and one from an area of the cultivar Regina surrounding trial plots. Three isolates were tested, all of which carried BYV1 alone.

INTRODUCTION

Despite 50% of the winter barley grown in the UK (NIAB, 2001a) being potentially susceptible to yellow rust (1-9 Disease resistance rating of 5 or less) the incidence of yellow rust in 2001 was again low. The bulk of the spring barley area remains resistant to yellow rust, with 66% of the area sown to cultivars having a resistance rating of 6 or above.

METHODS

Four samples of barley yellow rust were received in 2001. Three of the samples were collected from breeding lines, with the fourth sample from an area of Regina surrounding trial plots. Spores were successfully cultured from all four samples and three isolates (code B01/2, B01/3 and B01/4 in Table 2) were tested on seedlings of the differential cultivars listed in Table 1. The fourth isolate, B01/1, failed to produce sufficient spores to test.

Table 1. Differential cultivars used to test isolates of barley yellow rust in 2001.

Cultivar	BYR factor	Type *	Year virulence first detected
Astrix	1	O	) 1960
Atem	1	O	)
Bigo	2	O	)
Varunda	2	O	) 1972 – 75
Mazurka	2	S	)
Triumph	3	?S	1983

* O = overall , resistance effective at all growth stages
S = seedling, resistance ineffective at adult growth stages

Details of the samples received in 2001 are shown in Table 2.

Table 2. Locations and cultivars from which samples of yellow rust were collected in 2001.

Sample code	Source cultivar	Location
B01/1	Breeding line	Dunmow, Essex
B01/2	Regina	Spalding, Lincs.
B01/3	Breeding line	Spalding, Lincs.
B01/4	Breeding line	Spalding, Lincs.

RESULTS

All isolates tested in 2001 were virulent on the BYR1 differential, but were avirulent on the BYR2 and BYR3 differentials. Table 3 shows the virulence factor frequency for 1983 – 2001. The data illustrates trends in the frequencies over almost twenty years, but due to the low incidence of disease and samples, the results should be viewed with caution.

Table 3. Percentage frequency of barley yellow rust virulence factors for 1983 – 2001.

	'83	'84	'87	'89	'90	'91	'92	'93	'94	'95	'99	'00	'01
BYR1	100	100	100	100	100	100	100	100	100	100	100	86	100
BYR2	87	100	100	100	0	100	100	100	100	100	100	71	0
BYR3	17	86	22	75	0	0	0	0	100	0	100	71	0
No. of isolates	30	7	9	4	1	1	2	1	1	3	1	7	3

Although yellow rust of barley has not been a problem in the field since the early 1980's, with the continued introduction of susceptible cultivars an increase in the incidence of yellow rust remains a possibility. Three of the five winter barley cultivars added to the 2001 HGCA Recommended List (NIAB, 2001b) are susceptible to yellow rust i.e. Sumo (rating 5), Opal (rating 5) and Leonie (rating 4). Of the newly recommended spring barley cultivars two are susceptible to yellow rust (County, rating 5 and Cellar, rating 3). Fungicides applied in the field to control mildew and brown rust may also control low levels of yellow rust and prevent a build up of the disease on moderately resistant cultivars. However, the risk of yellow rust infection on cultivars such as County and Cellar may be increased as these cultivars are resistant to mildew and brown rust, so may receive little fungicide. The lack of competition from other fungal pathogens could also increase the risk of a build up of yellow rust from an initial infection.

REFERENCES

NIAB (2001a). Seed Production, Issue No. 29, August 2001.

NIAB (2001b). UK Recommended Lists of Cereals: 2001 cereals variety handbook.

BROWN RUST OF BARLEY

E.R.L. JONES

IGER, Plas Gogerddan, Aberystwyth, Ceredigion SY23 3EB

The highly resistant spring barley cvs, County, Tavern, Adonis, Cellar and Static, were susceptible as seedlings to some of the isolates cultured from the year 2001 samples. When tested as adult plants against one of these isolates, they were resistant in the glasshouse and field. Cultivar Jewel again expressed good levels of adult plant resistance as did a number of other winter barleys in field tests.

SEEDLING TESTS WITH YEAR 2001 ISOLATES

The seventy-two samples of barley brown rust received during the 2000-2001 season were from a range of winter barley cvs. The majority of the samples came from two trial sites, Headley Hall, North Yorkshire (32) and NIAB, Cambridge (35), (Table 1).

Table 1. Geographic origin (county) of 2001 brown rust samples

County of origin	Number of samples
Cambridgeshire	35
North Yorkshire	32
Norfolk	5

Isolates of *Puccinia hordei* Otth. were cultured from 41 samples and tested on a set of 10 differential cvs which carry different, identified Pa genes for resistance to *Puccinia hordei* (Table 2).

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

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
Trumpf	10	Pa_{10}	10

Also included in tests were the spring barley cvs County, Tavern, Adonis, Cellar and Static which have previously shown high levels of resistance, with those on the HGCA Recommended List having disease ratings of 8 or 9.

Results

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

Table 3. Races identified from 2001 isolates

Number of isolates	Octal designation	BBV factors
15	273	1,2,4,5,6,8
1	277	1,2,3,4,5,6,8
3	1653	1,2,4,6,8,9,10
5	1657	1,2,3,4,6,8,9,10
9	1673	1,2,4,5,6,8,9,10
8	1677	1,2,3,4,5,6,8,9,10

All have been identified previously. Only resistance conferred by Cebada Capa (BBR-7), virulence to which has not been identified in the UK, was effective against all the isolates. Cultivars County, Tavern, Adonis, Cellar and Static expressed a similar pattern of responses to the isolates. They were resistant to all isolates that do not carry virulence BBV-3. To those carrying this virulence factor, they expressed a mixed, mainly susceptible reaction to some and a mixed, mainly resistant reaction to the remainder.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF BROWN RUST

Adult plant tests

Winter and spring barleys were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included cvs on the HGCA Recommended Lists of winter and spring barleys, potential new cvs as well as the standard set of seedling differential cvs. Two replicates of each cv. were inoculated separately with each of the following isolates:

Isolate	BBV-	Race octal	Origin
BRS-01-07	1,2,4,5,6,8	273	cv. Jackpot, North Yorkshire
BRS-00-04	1,2,3,4,6,8,9,10	1657	cv. Pearl, Lancashire
BRS-01-02	1,2,3,4,6,8,9,10	1657	cv. Siberia, Cambridge

The plants were inoculated and incubated using methods described previously (Jones and Clifford, 1996). Plants were assessed on percentage flag leaf area infected as well as by reaction type on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4).

Seedling tests

Seedlings of the cvs included in adult plant test, plus additional potential new cvs, were grown in a spore-proofed glasshouse to the second leaf stage. They were inoculated with the same isolates under the same conditions as the adult plants. Assessments of infection type, classified on the standard 0-4 scale, were made on the first leaf.

Results

Winter barleys (Table 4)

All cvs were susceptible to all isolates as seedlings. Therefore cvs are classified into groups on the basis of similarities in the pattern of their adult responses to the isolates. Grouping does not necessarily imply that cvs within a group carry a common resistance factor(s).

Group 1: Cultivars susceptible.
Group 2: As adult plants, the cvs were susceptible only to isolate BRS-01-07. This isolate is less widely virulent than the other two isolates, but it is the only one to carry virulence factor BBV-5, suggesting that the resistance of these cvs may be conferred by BBR-5. Previous years' tests have shown, however, that some cvs included in Group 2 and which are susceptible to race octal 273, are resistant to some isolates carrying BBV-5. The reasons for this are unclear.
Group 3: Cultivar Jewel was resistant to isolate BRS-01-07 and, although it gave a susceptible reaction type to isolates BRS-00-04 and BRS-01-02, it was infected at low levels compared to Group 1 cvs. It was also adult plant resistant in year 2000 glasshouse tests to isolate BRS-00-04.
Group 4: A number of newly introduced cvs were tested as seedlings only. All were susceptible.

Spring barleys (Table 5)

Cultivars are again grouped within the table on the basis of similarities in the adult plant x isolate interactions. It should not be interpreted that cvs within a group carry a common resistance factor(s). Indeed, in certain cases cvs known to differ in BBR factor were classified within the same group in Table 5.

Group 1: The commercially grown cvs were highly susceptible. The differential cvs Sudan (BBR-1), Gold (BBR-4) and Bolivia (BBR-6), were also susceptible, the isolates having been identified as carrying the corresponding virulences in previous seedling tests.
Group 2: Cultivars Trumpf (BBR-10), Hordeum 2596 (BBR-9) and Estate (BBR-3) were susceptible to the two isolates carrying the corresponding virulences but resistant to isolate BRS-01-07. Also included in this group are cvs Optic and Chime, which previous tests suggest carry BBR-3, and the newly introduced cv. Spike.
Group 3a: Cultivars differ from those in the Group 2 by expressing adult plant resistance to isolate BRS-00-04. They were, however, susceptible to isolate BRS-01-02 which carries the same range of virulences, based on the reactions of the seedling differential cvs.
Group 3b: Previous years' tests have shown cv. Egypt 4 (BBR-8) to be resistant as an adult plant to some isolates demonstrated as carrying virulence factor BBV-8 in seedling tests. In 2001 tests, this adult plant resistance was overcome by isolate BRS-01-02 but maintained its

effectiveness to isolate BRS-00-04, against which it was also resistant in year 2000 tests. It was resistant to isolate BRS-01-07.

Group 4a: High levels of resistance have previously been shown by the cvs within this group, although some isolates have infected them (mixed susceptible reaction) in seedling tests. One such isolate, BRS-01-02 was included in these glasshouse tests where again it infected seedlings of the cvs but failed to overcome their resistance at the later growth stage. Isolate BRS-00-04, which carries the same range of virulences, based on the responses of the standard differential cvs, failed to infect them.

Group 4b: The differential cv. Cebada Capa (BBR-7), whose resistance has remained effective in the UK, was also resistant in these tests.

Group 4c: The adult plant resistance of cv. Peruvian (BBR-2) remained effective against the isolates, although they carried the corresponding virulence as demonstrated in seedling tests.

Group 5: Cultivar Quinn (BBR-5) was susceptible to the only isolate, BRS-01-07, carrying virulence factor BBR-5.

ADULT PLANT FIELD ISOLATION NURSERIES

Winter and spring barleys were sown during the 2000-2001 season. They included cvs on the HGCA Recommended Lists of winter and spring barleys, some members of the standard set of differential cvs, outmoded cvs and potential new cvs. Spores of isolate BRS-00-02 (race octal 1677), ex cv. Regina, Suffolk, were introduced artificially into the nurseries. This isolate was included in year 2000 glasshouse tests (Jones, 2001) and is virulent on seedlings of all the differential cvs comprising the standard set with the exception of cv. Cebada Capa (BBR-7).

Results

Plants were assessed on percentage leaf area infected and reaction type using the standard 0-4 scale where resistant (R) = 0-2, and susceptible (S) = 3-4.

Winter barleys (Table 6)

Reasonable levels of brown rust built up on the susceptible cvs.

The test cvs displayed a range in levels of susceptibility to the disease. Those cvs which had expressed resistance to the same isolate in year 2000 glasshouse tests were among the least heavily infected in the field. Cultivar Scylla, which was infected at only low levels in the field nursery was, however, very susceptible in glasshouse tests.

Spring barleys (Table 7)

High levels of disease built up on the susceptible spring barleys. Test cvs expressed a range of quantitative, susceptible and resistant responses to the introduced pathotype. Of the cvs resistant in the field, Cellar, Decanter, Static, Tavern, Saloon and County had previously been exposed to isolate BRS-00-02 in year 2000 glasshouse tests (Jones, 2001) when they were also resistant. Cultivar Optic, thought to carry resistance factor BBR-3, was highly resistant, although it had been heavily infected by the same isolate in the glasshouse. This field resistance was also evident in 1999 and 2000. The standard differential cvs Trumpf (BBR-10), Simon (BBR-3) and Quinn (BBR-5) were susceptible to isolate BRS-00-02, that carries corresponding virulence factors.

ACKNOWLEDGEMENTS

I am grateful to Dr Tim Carver (IGER) for his comments on this report. I thank Mr Warren Hutton (NIAB, Cambridge) for provision of seed of R.L. cvs.

REFERENCES

Jones, E.R.L. and Clifford, B.C. (1996). Brown rust of barley. *UK Cereal Pathogen Virulence Survey 1995 Annual Report*, pp.52-55.

Jones, E.R.L. (2001). Brown rust of barley. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp.68-75.

Table 4. *Reactions of winter barley cultivars, adult plants and seedlings ( ), to specific isolates of *Puccinia hordei* in glasshouse tests

Isolate / Cultivar [1-9 rating]	Group	BRS-00-04 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-01-02 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-01-07 (BBV-1,2,4,5,6,8) Race octal 273		
Scylla [7]	1	40	S	(S)	30	S	(S)	30	S	(S)
Vertige [6]		40	S	(S)	40	S	(S)	35	S	(S)
Vanessa [3]		35	S	(S)	40	S	(S)	38	S	(S)
Pict [5]		40	S	(S)	35	S	(S)	35	S	(S)
Regina [7]		35	S	(S)	40	S	(S)	38	S	(S)
Muscat [6]		40	S	(S)	40	S	(S)	30	S	(S)
Milena		28	S	(S)	35	S	(S)	40	S	(S)
Angela [8]		28	S	(S)	23	S	(S)	40	S	(S)
Diamond	2	13	MR	(S)	25	R	(S)	40	S	(S)
Chamomile		10	R	(S)	20	R	(S)	40	S	(S)
Avenue		10	R	(S)	8	R	(S)	40	S	(S)
Antonia [7]		13	MR	(S)	23	MR	(S)	35	S	(S)
Heligan [6]		0		(S)	0.5	MR	(S)	30	S	(S)
Opal [5]		18	R	(S)	18	R	(S)	28	MS	(S)
Sumo		35	R	(S)	25	R	(S)	28	S	(S)
Haka [8]		1	R	(S)	18	R	(S)	28	S	(S)
Pearl [7]		26	MR	(S)	13	R	(S)	23	S	(S)
Whisper		6	R	(S)	3	R	(S)	15	S	(S)
Jewel [7]	3	2	S	(S)	9	MS	(S)	4	R	(S)
Carat [5]	4			(S)			(S)			(S)
NSL96/7244				(S)			(S)			(S)
Pedigree				(S)			(S)			(S)
Sequel				(S)			(S)			(S)
NSL97/6016				(S)			(S)			(S)
Parasol				(S)			(S)			(S)
Kestrel				(S)			(S)			(S)
Clara				(S)			(S)			(S)
Antelope				(S)			(S)			(S)
Swallow				(S)			(S)			(S)

*Adult plants assessed on percentage area of flag leaf infected and reaction type
Mean of 2 plants
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

*Seedlings assessed on reaction type on 1st leaf.
[ ] Resistance rating: 1 = susceptible; 9 = resistant

Table 5. *Reactions of spring barley cultivars, adult plants and seedlings ( ), to specific isolates of *Puccinia hordei* in glasshouse tests

Isolate/ Cultiver [1-9 rating]	BBR-	Group	BRS-00-04 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-01-02 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-01-07 (BBV-1,2,4,5,6,8) Race octal 273		
Chalice [6]		1	43	S	(S)	40	S	(S)	43	S	(S)
Chariot [5]			33	S	(S)	55	S	(S)	55	S	(S)
Pewter [4]			33	S	(S)	45	S	(S)	45	S	(S)
Sudan	1		35	S	(S)	45	S	(S)	45	S	(S)
Gold	4		45	S	(S)	38	S	(S)	38	S	(S)
Bolivia	6		15	S	(S)	25	S	(S)	28	S	(S)
Chime		2	40	MS	(S)	40	S	(S)	18	R	(R)
Optic [8]			30	S	(S)	38	S	(S)	38	R	(R)
Spike			12	MS	(S)	33	MS	(S)	13	R	(MR)
Estate	3		30	S	(S)	25	S	(S)	0		(R)
Hordeum 2596	9		30	S	(S)	20	S	(S)	25	R	(R)
Trumpf	10		25	S	(S)	30	S	(S)	35	R	(R)
Decanter [7]		3a	25	MR	(S)	35	S	(S)	55	R	(MR)
Harriot			20	MR	(S)	35	S	(S)	18	R	(R)
Spire [7]			18	MR	(S)	35	S	(S)	18	R	(MR)
Egypt 4	8	3b	35	MR	(S)	30	MS	(S)	23	MR	(S)
Cellar [8]		4a	48	MR	(MR)	35	MR	(MS)	23	R	(R)
Saloon			40	R	(MR)	35	MR	(MS)	30	R	(MR)
Adonis			33	MR	(MR)	30	MR	(MS)	23	R	(R)
Static [8]			25	R	(MR)	33	R	(MS)	23	R	(R)
Tavern [9]			33	MR	(MR)	18	MR	(MS)	0		(R)
County [9]			30	R	(MR)	38	R	(MS)	0		(R)
Cebada Capa	7	4b	15	R	(R)	10	R	(R)	15	R	(R)
Peruvian	2	4c	40	MR	(S)	35	MR	(S)	40	MR	(S)
Quinn	5	5	0		(R)	8	R	(R)	35	S	(S)

*Adult plants assessed on percentage area of flag leaf infected and reaction type
Mean of 2 plants
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
*Seedlings assessed on reaction type on 1st leaf.
[ ] Resistance rating: 1 = susceptible; 9 = resistant

Table 6. *Reactions of winter barley cultivars to brown rust in a field nursery in 2001

Cultivar [1-9 rating]	% Infection	Reaction type
Manitou	20	S
Vertige [6]	19	S
Milena	18	S
Siberia [5]	15	S
Leonie [6]	15	S
Vanessa [3]	13	S
Regina [7]	12	S
Fanfare [7]	11	S
Jackpot	11	S
Carat [5]	9	S
Gleam	9	S
Pict [5]	8	S
Pastoral [5]	6	S
Sumo [7]	5	S
Muscat [6]	4	S
Antonia [7]	2	S
Heligan [6]	2	S
Pearl [7]	2	S
Intro	2	S
Jewel [7]	2	S
Avenue	2	S
Opal [5]	2	S
Chamomile	2	S
Scylla [7]	2	S
Diamond	2	S
Flute	1	S
Angela [8]	1	S
Whisper	0.3	S
Haka [8]	0.2	S

*Mean of 4 replicates, final assessment date
S = susceptible (3-4 type reaction)

Table 7. *Reactions of spring barley cultivars to brown rust in a field nursery in 2001

Cultivar [1-9 rating]	BBR factor	% Infection	Reaction type
Riviera [5]		35	S
Chalice [6]		33	S
Chariot [5]		33	S
Trumpf	10	31	S
Prisma [5]		30	S
Quinn	5	29	S
Pewter [4]		28	S
Simon	3	21	S
Chime		16	S
Spike		6	S
Spire [7]		5	MS
Cellar [8]		15	MR
Decanter [7]		14	MR
Static [8]		12	R
Adonis		6	MR
Tavern [9]		5	MR
Harriot		5	R
Saloon		4	R
County [9]		3	R
Optic [8]		2	R

*Mean of 4 replicates, final assessment date
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
[ ] Resistance 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
†Scottish Crop Research Institute, Invergowrie, Dundee

Virulence to cv. Digger (BRR-8), which has remained at a low frequency, was identified in 3 isolates cultured from the 2001 samples. One of these isolates was the only one to infect the generally highly resistant spring barley cv. Pewter. Glasshouse tests with specific isolates of the pathogen identified several currently recommended and potential new cvs as carrying the race specific resistance BRR-2. Adult plant field tests identified possible increased virulence to cv. Regina. The current HGCA Recommended List spring barleys continue to be highly susceptible with only cv. Pewter expressing resistance.

SEEDLING TESTS WITH YEAR 2001 ISOLATES

Leaf samples of *Rhynchosporium secalis* were received from a range of winter (95) and spring (17) barleys. The geographic origins of the samples are given in Table 1. All samples received from N. Yorkshire were from winter and spring barley trial sites at Headley Hall, and all those from Cambridgeshire from a NIAB winter barley trial.

Table 1. Geographic origins (county) of *Rhynchosporium* samples received in year 2001

County of origin	No. of samples	County of origin	No. of samples
North Yorkshire	45	Shropshire	5
Cambridgeshire	29	Suffolk	4
Kent	9	Mid Glamorgan	2
Northumberland	8	Lincolnshire	1
Norfolk	8	County Down	1

Viable spore suspensions were obtained from 85 of the samples and were tested on the standard set of differential cvs (Table 2). Also included in the tests was cv. Pewter which has generally shown high levels of resistance.

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

The frequencies of individual virulences identified from the isolates are shown in Table3, where they are compared with those of previous seasons.

Table 3. Frequencies of individual virulences, 1991-2001

	BRV-								No. of
Year	8	7	6	5	4	3	2	1	isolates
2001	0.04	0.80	0.02	0.04	0.94	0.99	0.89	0.89	85
2000	0.05	0.70	0.05	0.05	0.78	1.00	0.75	0.75	40
1999	0	0.32	0.16	0.20	0.64	1.00	0.76	0.76	25
1997	0.02	0.37	0.02	0.02	0.96	1.00	0.31	0.31	45
1995	-	0.26	0.13	0.30	0.65	0.91	0.26	0.26	23
1993	-	0.57	0.07	0.12	0.94	1.00	0.68	0.68	69
1991	-	0.28	0	0	0.52	0.74	0.22	0.22	50

Virulence to BRR-1 and BRR-2 was, as in recent years, at a high frequency. This is attributable to the large proportion of samples being from winter barleys, many of which carry BRR-2. Cultivar Digger (BRR-8) was susceptible to three isolates. One of these, isolate RS-01-09 (ex cv. Demon, Cambs), was the only one to infect cv. Pewter at sufficiently high levels (10%+) for this spring barley to be classified as susceptible. The other two Digger virulent isolates also infected cv. Pewter at higher levels (5%) than the remainder of the year 2001 isolates.

The virulences identified occurred in various combinations in the different isolates (Table 4). One isolate, RS-01-25, failed to infect any of the cv, whilst the most complex virulence combination identified, race octal 177, carried virulence to all the differential cvs with the exception of cv. Digger. This previously identified race was found in one isolate, cultured from cv. Chamomile sampled in Shropshire. Two new races, octal 57 and 154, were found. Both carry BRV-6, which has remained at a low frequency in the population, but lack virulence to BRR-5 (La Mesita). Isolates previously identified as carrying BRV-6 have also carried BRV-5.

Table 4. Virulence factor combinations identified from 2001 isolates

No. of	Differential cultivars in linear order								Race
isolates	Digger	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	octal
1	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	1	0	0	4
3	0	0	0	0	1	1	0	0	14
1	0	0	0	1	0	1	0	0	24
2	0	1	0	0	1	1	0	0	114
1	0	1	1	0	1	1	0	0	154
10	0	0	0	0	1	1	1	1	17
1	0	0	1	0	1	1	1	1	57
1	0	1	0	0	0	1	1	1	107
59	0	1	0	0	1	1	1	1	117
1	0	1	0	1	0	1	1	1	127
1	0	1	1	1	1	1	1	1	177
3	1	1	0	0	1	1	1	1	317

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 cvs on the HGCA Recommended List of winter and spring barleys as well as the standard set of seedling differential cvs. Two replicates of each cv. were inoculated separately with each of the following isolates:

Isolate	†BRV-(race octal)	Origin
RS-00-19	3,5,6,7 (164)	cv. Pipkin, Tayside
RS-01-42	1,2,3,4,7 (117)	cv. Regina, Kent
RS-00-20	3,4,7,8 (314)	cv. Livet, Tayside

† identified in seedling tests

Following inoculation, the plants were placed in dew simulation chambers in the dark at 15°C for 24 h post-inoculation and then incubated in the glasshouse at approximately 15°C for 14 days. Assessments were made of infection levels on the flag leaves.

Seedling tests

Seedlings of several of the cvs included in adult plant tests, together with some potential new winter and spring barleys, were grown to the second leaf stage. They were inoculated with the same isolates and incubated under the same conditions as the adult plants. Seedling reactions were assessed by infection levels on the second leaf and classified as resistant (R) or susceptible (S).

Results

Winter barleys (Table 5):

No results were obtained for adult plants inoculated with isolate RS-01-42, as the dew chamber malfunctioned. Cultivars are grouped within the table on the basis of similarities in the patterns of their adult plant responses and on their seedling reactions. Grouping does not necessarily imply that cvs within a group carry a common resistance factor(s).

Group 1: Cultivars were susceptible as seedlings to all isolates. Those cvs tested as adult plants were generally more heavily infected by isolate RS-00-19 than RS-00-20, although cv. rankings showed a similar pattern between isolates.
Group 2: Cultivars were resistant to two of the isolates but were susceptible as seedlings to isolate RS-01-42. This is the only isolate in these tests to carry virulence factors BRV-1 and BRV-2. The differential cv. Astrix (BRR-2) is included within this group.
Group 3: Cultivar Igri (BRR-4) was susceptible to the two isolates RS-01-42 and RS-00-20, identified in seedling tests as carrying the corresponding virulence BRV-4.
Group 4: Cultivar Leonie, previously identified as carrying BRR-5, was infected by isolate RS-00-19 only. Cultivar Clara expressed a similar pattern of responses to the isolates.

Spring barleys (Table 6):

Previous years' tests have shown several of the current HGCA Recommended List spring barleys to be highly susceptible to leaf scald. The majority of these were, therefore, not included in 2001 tests. Again, no results were obtained for adult plants inoculated with isolate RS-01-42. Cultivars are grouped within the table on the basis of similarities in host/pathogen interactions.

Group 1: Cultivars were susceptible as seedling and adult plants. Cultivar Tavern, inoculated with RS-00-20, showed infection levels of 30% on its flag leaf, although it had been resistant to the same isolate in adult plant tests in year 2000.
Group 2: Cultivar Armelle (BRR-1) was susceptible to RS-01-42, the only isolate carrying the corresponding virulence.

Group 3: Isolate RS-00-19 infected cv. La Mesita (BRR-5) in seedling and adult plant tests. Cultivar La Mesita was also susceptible as an adult plant to isolate RS-00-20, although in seedling tests it remained resistant. It is a characteristic of many cvs carrying resistance factor BRR-5 that they are susceptible at later growth stages to isolates not identified as carrying the corresponding virulence factor BRV-5 in seedling tests.
Group 4: BRV-6 remains at a low frequency in the UK pathogen populations but the virulence is carried by isolate RS-00-19, which overcame the overall resistance of cv. Osiris (BRR-6).
Group 5: Virulence to BRR-8, carried by the standard differential cv. Digger, is also at a low frequency in the population. The susceptible reaction of cv. Digger to RS-00-20 confirms that this isolate carries the corresponding virulence factor BRV-8.
Group 6: Cultivar Pewter, which has generally shown high levels of resistance in the field, was infected at low levels in adult plant tests. It was, however, susceptible as a seedling to isolate RS-00-20. These results, together with data from other seedling tests, suggest that cv. Pewter can be infected by isolates virulent on cv. Digger. However, the levels of infection are generally so low that cv. Pewter is classified as resistant.

ADULT PLANT FIELD ISOLATION NURSERIES

Winter and spring barley nurseries were grown during the 2000-2001 season. Included in tests were cvs on the HGCA Recommended Lists of winter and spring barleys, potential new cvs, outmoded cvs and cvs carrying known specific resistances and used as differentials in seedling tests. These are grown on a site conducive to the development of the disease which has previously been allowed to develop from endemic inoculum. In 2001, however, isolate RS-00-02 was introduced artificially into the nursery. This isolate was cultured from a heavily infected sample of cv. Regina grown in Suffolk. In year 2000 glasshouse tests (Jones, 2001) it induced high levels (60%) of disease on cv. Regina.

Results

Winter barleys (Table 7):

Disease levels built up slowly but increased readily late in the season when susceptible cvs were quite heavily infected. Cultivars showed quantitative variation in disease levels with rankings between them generally corresponding to their 1-9 disease resistance ratings. Cultivar Regina showed higher levels of infection (20%) than it had in the previous years' nursery (11%), although variations in climate which influences disease development makes it difficult to compare between seasons. It would appear, however, that pathotypes exist in the population which can infect cv. Regina at increased levels. The outmoded cv. Manitou again expressed high levels of resistance, as it has over a number of seasons.

Spring barleys (Table 8):

High levels of disease built up within the nursery. Of the HGCA Recommended List cultivars, only the resistance carried by cv. Pewter was effective. Also infected at very low levels were the differential cvs Armelle (BBR-1), Osiris (BBR-6) and Digger (BBR-8), although cv. Armelle was susceptible to the isolate BRS-00-02 in glasshouse tests. It is likely that the artificially introduced pathotype was swamped by other pathotypes as the season progressed.

ADULT PLANT FIELD NURSERY AT SCRI

A nursery, comprising cvs from the 2001 HGCA Recommended List of spring barleys, together with winter and spring barleys carrying known specific resistances, was sown during the spring of 2001. Disease was allowed to develop naturally within the nursery.

Results (Table 9)

Assessments of percentage leaf area infected were made throughout the season. Cultivars differed in the levels of disease they developed under natural infection. The most susceptible cvs were very heavily infected. Cultivar Pewter was infected at relatively low levels as were the differential cvs Digger, Osiris, Astrix, Armelle and Athene. Of the differential cvs, only cv. Pirate (BBR-7) and cv. La Mesita (BBR-5) were infected at sufficiently high levels to be classified as susceptible.

ACKNOWLEDGEMENTS

I am grateful to Dr Tim Carver (IGER) for his comments on this report. I thank Mr Warren Hutton (NIAB, Cambridge) for provision of seed of R.L. cvs.

REFERENCE

Jones, E.R.L. and Newton, A.C. (2001) *Rhynchosporium* of barley. *UK Cereal Pathogen Virulence Survey 2000 Annual Report*, pp.77-86.

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

Cultivar/isolate [1-9 rating]	Group	RS-00-19 (Race octal 164) BRV-3,5,6,7	RS-01-42 (Race octal 117) BRV-1,2,3,4,7	RS-00-20 (Race octal 314) BRV-3,4,7,8
Pastoral [7]	1	55 (S)	- (S)	35 (S)
Pearl [8]		50 (S)	- (S)	35 (S)
Scylla [6]		40 (S)	- (S)	25 (S)
Carat [7]		33 (S)	- (S)	25 (S)
Antonia [8]		30 (S)	- (S)	30 (S)
Muscat [8]		30 (S)	- (S)	25 (S)
Haka [6]		27 (S)	- (S)	18 (S)
Jewel [8]		20 (S)	- (S)	15 (S)
Opal [7]		18 (S)	- (S)	15 (S)
NSL 96/7244		- (S)	- (S)	- (S)
Sequel		- (S)	- (S)	- (S)
Athene BRR-3		- (S)	- (S)	- (S)
Siberia [7]	2	0 (R)	- (S)	1 (R)
Vanessa [8]		0 (R)	- (S)	0 (R)
Angela [8]		1 (R)	- (S)	2 (R)
Chamomile		0 (R)	- (S)	0 (R)
Whisper		0 (R)	- (S)	0 (R)
Avenue		0 (R)	- (S)	0 (R)
Regina [7]		- (R)	- (S)	- (R)
Diamond		- (R)	- (S)	- (R)
Pict [8]		- (R)	- (S)	- (R)
Kestrel		- (R)	- (S)	- (R)
Antelope		- (R)	- (S)	- (R)
Swallow		- (R)	- (S)	- (R)
Astrix BRR-2		- (R)	- (S)	- (R)
Igri BRR-4	3	- (R)	- (S)	- (S)
Leonie [9]	4	- (S)	- (R)	- (R)
Clara		- (S)	- (R)	- (R)

*Adult plants assessed on percentage area of flag leaf infected
Mean of 2 plants
Not tested
Seedlings assessed on 2nd leaf and classified as resistant (R) or susceptible (S)
[ ] Disease resistance 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 [1-9 rating]	BRR factor	Group	RS-00-19 (Race octal 164) BRV-3,5,6,7		RS-01-42 (Race octal 117) BRV-1,2,3,4,7		RS-00-20 (Race octal 314) BRV-3,4,7,8	
Spire [4]		1	85	(S)	-	(S)	50	(S)
Spike			75	(S)	-	(S)	50	(S)
Adonis			75	(S)	-	(S)	35	(S)
Cellar [4]			60	(S)	-	(S)	40	(S)
Harriot			50	(S)	-	(S)	40	(S)
Tavern [6]			35	(S)	-	(S)	30	(S)
Armelle	1	2	0.3	(R)	-	(S)	0.1	(R)
La Mesita	5	3	80	(S)	-	(R)	40	(R)
Osiris	6	4	10	(S)	-	(R)	0.5	(R)
Digger	8	5	1	(R)	-	(R)	25	(S)
Pewter [7]		6	0.5	(R)	-	(R)	2	(S)

*Adult plants assessed on percentage area of flag leaf infected
Mean of 2 plants.
Seedlings assessed on 2nd leaf and classified as
resistant (R) or susceptible (S)
[ ] Disease resistance rating: 1 = susceptible; 9 = resistant

Table 7. *Infection of winter barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2001

Cultivar [1-9 rating]	BRR factor	% infection
Avenue		29
Otter		28
Athene	3	28
Vertige [5]		28
NSL 96/6017		26
Intro		25
Milena		25
Igri	4	25
Heligan [6]		24
Scylla [6]		23
Astrix	2	23
Whisper		21
Pastoral [7]		21
Sumo [5]		20
Regina [7]		20
Pict [8]		20
Opal [7]		19
Haka [6]		19
Gleam		18
Chamomile		18
Pearl [8]		16
Fanfare [8]		16
Vanessa [8]		15
Flute		14
Pirate	7	13
Antonia [8]		13
Diamond		13
Muscat [8]		12
Jewel [8]		12
Jackpot		10
Siberia [7]		10
Leonie [9]		10
Angela [8]		8
Manitou		4

*Mean of 4 replicates, final assessment date
[ ] Disease resistance rating: 1 = susceptible; 9 = resistant

Table 8. *Infection of spring barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2001

Cultivar [1-9 rating]	BRR factor	% infection
Cellar [4]		54
Chariot [4]		54
Spike		48
Spire [4]		47
Chalice [6]		46
County [6]		46
Decanter [5]		45
Saloon		45
Adonis		45
Optic [4]		44
Chime		44
Static [5]		43
Prisma [6]		41
Riviera [5]		41
La Mesita	5	41
Harriot		36
Tavern [6]		34
Pewter [7]		3
Armelle	1	3
Digger	8	0.3
Osiris	6	0.3

*Mean of 4 replicates, 2 assessment dates
[ ] Disease resistance rating: 1 = susceptible; 9 = resistant

Table 9. *Infection of barley cultivars by *Rhynchosporium secalis* in a SCRI field nursery in 2001

Cultivar [1-9 rating]	BRR factor	Mean % infection
Chariot [4]		50
Prisma [6]		38
Static [5]		37
Chime		30
Adonis		29
County [6]		27
Saloon		27
Riviera		27
Optic [4]		23
Cellar [4]		20
Decanter [5]		20
Chalice [6]		19
Harriot		18
Spire [4]		17
La Mesita	5	17
Pirate	7	16
Spike		15
Tavern [6]		12
Pewter [7]		7
Digger	8	5
Livet		4
Osiris	6	3
Astrix	2	3
Armelle	1	1
Athene	3	0

SED = 5.41

*Mean of 4 replicates, 3 assessment dates

[ ] Disease resistance 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.

Cultivars on the current HGCA Recommended List of winter barleys displayed a range of quantitative responses to the inoculum of *Pyrenophora teres* Drechs. against which they were tested. Cultivars Angela and Pearl were less heavily infected than would be expected from their disease ratings. They had also shown relatively low levels of infection in similar tests in year 2000. Of the potential new cvs, only cv. Sequel was resistant as a seedling.

INTRODUCTION

Twenty-one samples from a range of winter barley cvs were received. Of these, 19 were from a site at NIAB, Cambridge, and the other two were from different locations in Suffolk.

The samples were not tested individually on the standard set of seedling differential cvs, but a mixed inoculum prepared from all the samples were sprayed onto seedlings and/or adult plants of a number of cvs.

GLASSHOUSE TESTS WITH YEAR 2001 ISOLATES

Adult plant tests

Barley cvs were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included those cvs on the HGCA Recommended List of winter barleys, potential new winter barley cvs as well as the standard set of differential cvs. Two replicates of each cv. were inoculated and then placed in dew chambers in the dark at 15°C for 24 hrs. They were then placed in the glasshouse at approximately 15°C for 12 days. Assessments were made of percentage flag leaf area infected.

Seedling tests

Seedlings of the cvs used in adult tests, together with additional potential new cvs, were grown to the second leaf stage, inoculated with the same mixture of isolates and incubated 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 = (R: 0-2) or susceptible = (S: 3-4).

Results (Table 1)

Disease symptoms on the adult plants were mainly of a striping or blotching type whereas those on the seedlings were generally of a netting type. Cultivars differed in the levels of disease they developed with the susceptible cv. Siberia, showing high levels of infection (60%). Cultivars Angela and Pearl, which have 1-9 disease resistance ratings of 5, were relatively resistant showing disease levels similar to those they had expressed in year 2000 tests. The seedling resistance of cv. Angela was effective as it had been to the mixtures of the isolates against which it was tested in 1999 and 2000. Cultivar Leonie, with a disease rating of 9, was seedling resistant and also showed good levels of resistance as an adult plant.

The potential new cvs which were included in seedling tests only were susceptible with exception of cv. Sequel.

The seedling responses of the differential cvs identified the pathotype mixture as carrying virulences 4,8,9,11,12.

ACKNOWLEDGEMENT

I thank Mr Warren Hutton (NIAB, Cambridge) for provision of seed of R.L. cvs.

REFERENCE

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

Table 1. *Reactions of winter barley cultivars, adult plants and seedling, to a mixture of net blotch isolates in glasshouse tests

Cultivar [1-9 Rating]	Adult plant % infection	Seedling reaction	Cultivar	Differential code number	Adult plant % infection	Seedling reaction
Siberia [4]	60	S	CI 5401	1	4	R
Vanessa [7]	25	S	CI 6311	2	0.5	R
Scylla [8]	25	S	CI 9820	3	2	R
Pict [6]	23	S	CI 739	4	4	S
Muscat [5]	20	S	CI 1243	5	5	R
Diamond	20	S	CI 4795	6	5	R
Regina [6]	18	S	CI 4502	7	2	R
Heligan [7]	15	S	CI 4979	8	3	S
Whisper	15	-	Proctor	9	10	S
Pearl [5]	10	S	CI 9214	10	4	R
Haka [7]	10	S	CI 9518	11	33	S
Angela [5]	8	R	Tenn 61-119	12	18	S
Jewel [6]	8	S	Code 65	13	1	R
Sumo [7]	8	S	Swallow			S
Chamomile	8	S	Vertige			S
Opal [6]	6	S	NSL 96/7244			S
Fanfare [7]	5	S	Pedigree			S
Pastoral [8]	5	S	NSL 97/6016			S
Carat [8]	5	S	Parasol			S
Milena	5	S	Kestrel			S
Leonie [9]	5	R	Clara			S
Antonia [8]	2	S	Antelope			S
			Sequel			R

* Adult plants assessed on % flag leaf area infected, mean of 2 plants
Seedlings assessed on reaction type on a 0-4 scale
0-2 type reaction - resistant (R), 3-4 type reaction - susceptible (S)
[ ] Disease resistance rating: 1 = susceptible; 9 = resistant

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

M.J. ADAMS

IACR-Rothamsted, Harpenden, Herts., AL5 2JQ

Only 19 infected samples were received in 2001, of which 17 contained BaYMV and 5 had BaMMV. Most samples were from Pearl. There were insufficient data to analyse cultivar differences.

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 (*rym4*) 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, mostly as a result of publicity by the Arable Research Centres. Leaves were tested by enzyme-linked immunosorbent assay (ELISA) for the presence of both viruses as described by Adams (1990).

RESULTS AND DISCUSSION

19 infected samples were received in 2001 of which 17 contained BaYMV and 5 BaMMV (Table 1). Most samples were from Pearl. There were insufficient data to make any sensible analysis of cultivar differences.

Table 1. Mosaic virus samples from 2001, classified by cultivar.

Cultivar	BaMMV alone	BaYMV alone	Both viruses	Total samples
Heligan	0	2	0	2
Pearl	2	9	3	14
Regina	0	3	0	3
TOTAL	2	14	3	19

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

Mildew was late to establish in 2001, particularly on the winter crop. Only eleven samples were received, all from spring oat cvs (Table 1).

Table 1. Geographic and cultivar origins of oat mildew samples received in 2001

Location (county)	Cultivar
Northumberland	Drummer, Dula, Amigo
Cambridgeshire	Winston, Firth, Banquo, Amigo, Drummer, Dulo
Ceredigion	Cc4146, 07718 Cn/20/3/1

Isolates of *Blumeria graminis* DC Speer f.sp. *avenae* were cultured and tested on seedlings of the differential cvs (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

The isolates were all identified as the widely virulent race 5 (OMV-1,2,3) which has been at a high frequency in the pathogen population since the decline in frequency of the 'simpler' races 2,3 and 4 during the 1970s. OMV-4 has remained at low frequency since it was first identified in 1980, and it was not carried by the 2001 isolates.

CROWN RUST OF OATS

E.R.L. JONES

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

Only one sample of crown rust was received in 2001. This was from a plot of cv. Dula grown at NIAB, Cambridge. The isolate of *Puccinia coronata* cultured from it was tested on seedlings of the standard set of 10 differential cvs. The winter oat, cv. Millennium was also included. Virulence to the previously highly resistant cv. Millennium was identified in 1999 but it has maintained a 1-9 disease resistance rating of 9 (resistant).

RESULTS

Based on the responses of the differential cvs, the isolate CRS-01-01 was assigned the race number 251 from the International Register of Pathogenic Races of *Puccinia coronata*. This has been the most frequently identified race in recent seasons and carries virulence to the differential cvs Appler, Bond and Saia. Resistance conferred by cv. Millennium was effective, although 8 of the 11 isolates identified as carrying Millennium virulence in year 2000 were members of race 251.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 2002

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 2000 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 background 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 & Bayles (1980). Evidence that the schemes are effective in reducing the spread of disease has been summarised by Priestley & Bayles (1982) and the use of cultivar mixtures as a method of disease control has been reviewed by Wolfe, Barrett & 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 SPREAD OF YELLOW RUST IN WHEAT, 2002.

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
*(*)*
Charger
Claire
Deben
Malacca
Option
Soissons
Solstice
Xi19
Ambient (S)
Ashby (S)
Chablis (S)
Imp (S)
Morph (S)
Paragon (S)

DG1 contd

Shiraz (S)
Wallace (S)

DG3
WYR13
Riband

DG7
(WYR CV+)
Consort
Hereward
Shamrock

DG9
(WYR9&WYR17+)
Biscay
Buchan
Savannah
Tanker

(S) = *spring cv.*

DG10
(WYR6,17+)
Access
Equinox
Genghis
Madrigal
Napier

Companion DG

Chosen DG	1	3	7	9	10
1	+	+	+	+	+
3	+	Y	y	y	y
7	+	y	Y	y	+
9	+	y	y	Y	Y
10	+	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.

VARIETY DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY, 2002

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) & resistance genes (*Ml* or *ml*)
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*
Resistant Spring cvs (mlo)
Adonis (S)
Cellar (S)
Chalice (S)
Chariot (S)
Chime (S)
Dandy (S)
Decanter (S)
Harriot (S)
Pewter (S)
Riviera (S)
Saloon (S)
Static (S)
Resistant Winter cvs
Angela (W)
Leonie (W)
Milena (W)
Pearl (W)
Vanessa (W)

DG4 *Mla13*
Spike (S)
Spire (S)

DG5 *Mla12*
Carat (W)
Diamond (W)
Flute (W)
Jewel (W)

DG7 *Mla1*
County (S)
Delibes (S)
Tavern (S)

DG8 *Mla9*
Manitou (W)

DG9 *Mla12, Ml(Ab)*
Optic (S)

DG10 *Mla6*
Gleam (W)

DG0†
Mlra/Mlh/Mlg/Mla7
Antonia (W)
Avenue (W)
Chamomile (W)
Fanfare (W)
Haka (W)
Heligan (W)
Intro (W)
Muscat (W)
Opal (W)
Pastoral (W)
Pict (W)
Regina (W)
Scylla (W)
Siberia (W)
Sumo (W)
Vertige (W)
Whisper (W)
Mlg,Ml(CP),Mla12,Ml(Ab)
Prisma (S)

(W) Winter barley; (S) Spring barley
[2002 Recommended List cvs in **Bold**]

Companion DG

Chosen DG	1	4	5	7	8	9	10	0
1	+	+	+	+	+	+	+	+
4	+	M	+	+	+	+	+	M
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	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