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]

2000 Annual Report

Editor: J D S Clarkson

Published by
The United Kingdom Cereal Pathogen Virulence Survey Committee
Cambridge, England
April 2001

Price £20-00

Printed by NIAB, Cambridge

MEMBERS OF THE UK CEREAL PATHOGEN VIRULENCE SURVEY COMMITTEE, 2000-2001

Dr M J Adams	IACR-Rothamsted, Harpenden
Dr R A Bayles	NIAB, Cambridge
Dr L A Boyd	John Innes Centre, Norwich
Dr J K M Brown	John Innes Centre, Norwich
Dr T L W Carver	Institute of Grassland & Environmental Research, Aberystwyth
Mr W S Clark	ADAS, Boxworth
Mr J Clarke	Association of Independent Crop Consultants
Mr J D S Clarkson	NIAB, Cambridge
Mr D Feuerhelm	British Society of Plant Breeders
Dr N V Hardwick	Central Science Laboratory, York
Mr G J Hilton	NIAB, Cambridge
Dr R Johnson	Great Shelford, Cambridge
Mr E R L Jones	Institute of Grassland & Environmental Research, Aberystwyth
Dr P C Mercer	Department of Agriculture and Rural Development, Belfast
Dr A C Newton	Scottish Crop Research Institute, Dundee
Mrs S E Slater	NIAB, Cambridge
Mr P L Stigwood	NIAB, Cambridge

CONTENTS

THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

OBJECTIVES

The principal objective of the survey is the early detection of increased virulence compatible with resistances being exploited in commercial cultivars and breeding programmes.

Secondary objectives include providing information for cultivar diversification schemes, monitoring the frequency of virulences and virulence combinations, measuring the effect of changes in cultivar on the pathogen population and detecting fungicide insensitivity in some pathogens.

METHODS

The Survey is carried out annually. In April, a list of cereal cultivars from which disease samples are requested is sent to about 100 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 cultivar diversification schemes, modified to meet regional requirements, are published by NIAB and by SAC in Scotland.

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

REFERENCES

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

EXPLANATION OF TERMS USED TO DESCRIBE RESISTANCE AND VIRULENCE

SPECIFIC RESISTANCE AND SPECIFIC VIRULENCE

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

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

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

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

TERMS DESCRIBING RESISTANCE AT DIFFERENT GROWTH STAGES

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

- overall resistances -
  are effective at **all** growth stages.
- seedling resistances -
  are effective at **seedling** growth stages, but ineffective at adult plant growth stages.
- adult plant resistances -
  are effective at **adult plant** growth stages, but ineffective at seedling growth stages.

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 2000: SUMMARIES of PAPERS

- **WINTER CEREAL DISEASE SURVEYS, 2000**

A total of 406 randomly selected fields of winter barley and 419 similarly selected fields of winter wheat were sampled as part of the 2000 national survey of cereal diseases. The total foliar disease recorded on the top two leaves of winter barley (10.3%) was less than in 1999 (12.1%) and 1998 (18.2%). However, leaf blotch remained the most severe and widespread of the barley foliar diseases, affecting on average 5.2% of the area of leaf 2 and being recorded in 93% crops from the stratified sample. This was the highest level recorded since 1983. Although less severe than in any survey since 1995, net blotch was the second most severe disease, affecting 65% of samples with 1.1% area leaf 2 affected. Brown rust, at 0.6% area of leaf 2 affected, was at its lowest severity recorded since 1996, when 0.1% area of leaf 2 was affected. Mildew was recorded less frequently than in 1999 and affected 0.6% of leaf 2 compared with 1.0% and 0.8% recorded in 1999 and 1998, respectively. Leaf spot and halo spot were recorded at trace levels and yellow rust was not recorded. The percentage tillers affected by moderate plus severe lesions of eyespot (17.9%), was the highest recorded since 1993. Of the winter wheat diseases, septoria leaf blotch was the most severe foliar disease for the tenth consecutive year, affecting 7.2% of the area of leaf 2 compared with 6.7% in 1999, 7.7% in 1998 and 3.1% in 1997. Septoria leaf blotch was also present at trace levels on the ears. Glume blotch was the next most common and severe foliar disease, being recorded in 48.5% of the stratified sample, and affecting an average of 0.3% area leaf 2 but occurring only at trace levels on leaf 1 and the ear. Brown rust levels, at 0.1% of the area of leaf 2, fell to those recorded in earlier surveys following the previous two years of high levels in 1998 and 1999 (0.3% and 0.7% on leaf 2 respectively). Mildew affected 0.1% of the area of leaf 2, which equalled the lowest ever level recorded in 1998. Yellow rust was recorded at trace levels on both leaves 1 and 2 but was absent from the ear. Moderate plus severe levels of eyespot were the highest recorded since stem base diseases were included in the survey in 1975. The regional incidence and effect of cultivar on disease levels are also reported and the implications discussed.

- **MILDEW OF WHEAT**

Mildew levels were higher in 2000 than in 1998 and 1999. Virulence frequencies for Pm2, Pm4b, Pm6 and Pm8 were very high. The mildew population is becoming less complex, with one predominant pathotype – V2,4b,5,6,8,Ta2 – present in 61% of isolates and able to infect cultivars accounting for nearly three-quarters of the winter wheat area. 16 of the 18 2001 Recommended winter wheat cultivars are potentially susceptible to at least 97% of mildew isolates, although this is offset by effective partial resistance in many important cultivars. Recent new cultivars are generally mildew-susceptible, carrying no effective specific resistance genes, with the possible exception of Shamrock. 3 out of 123 bulk isolates tested were insensitive to strobilurin fungicides.

- **YELLOW RUST OF WHEAT**

Yellow rust was widespread in 2000 for the fourth consecutive year. 96% of isolates tested possessed virulence for WYR17 and 28% possessed virulence for WYR 6,17. Isolates with combined virulence for WYR6 and WYR17 were widely distributed throughout England. Isolates capable of overcoming the resistance of the cultivar Oxbow were detected for the first time. These isolates carried the virulence combination WYV1,2,3,4,9,17,CV together with virulence for Oxbow.

- **BROWN RUST OF WHEAT**

WBV-7 was found at an increased frequency in the year 2000 isolates. Several of the current NIAB Recommended List winter wheats are postulated as carrying Lr gene 37, whose resistance remains effective in the field. A number of other winter and spring wheats were also resistant. Resistance conferred by Lr genes 9, 19 and 24 remained effective against the UK pathotypes.

- **MILDEW OF BARLEY**

Virulence frequencies were similar to previous years. Barley mildew isolates continue to become more complex, the majority carrying eight or more virulence factors. Although nearly 200 pathotypes were detected in 2000, the number of pathotypes continued to decline. The dominant pathotype, *Vh,Vra,Vg,V(CP),VLa,Va12,Vk1,Va7,V(Ab),Va1*, although present in only 10% of the isolates tested, has become more frequent over the last few years. Of the winter cultivars, only Vanessa and Leonie have effective specific resistance, although many have good non-specific resistance. *Mlo* remains the only effective resistance in spring cultivars; isolates from 1998 and 1999 continued to give low levels of infection on *mlo* cultivars. No reduced sensitivity to strobilurins was detected.

Mildew in Northern Ireland continued at a low level, due to a combination of weather conditions and a high proportion of *mlo* cultivars. Isolates had a slight tendency towards increased virulence on *mlo* differential cultivars, although there was no evidence of field breakdown. Virulence for *Mla3* showed an unexpected rise.

- **YELLOW RUST OF BARLEY**

Seven samples of barley yellow rust were received or collected in 2000, the highest number since 1987. The isolates obtained from the samples exhibited a range of virulence to the differential varieties. Some winter barley RL and RL candidate varieties appeared to possess resistance to a number of these isolates, whilst other varieties did not appear to possess any specific resistance.

- **BROWN RUST OF BARLEY**

The majority of current winter barley cultivars were susceptible in glasshouse tests but some of these were infected at only low levels in field nurseries. Of the spring barleys, some expressed resistance in the field and in the glasshouse to pathotypes carrying different combinations of virulences. This resistance was of the overall type in some cultivars but of the adult plant type in others.

- **RHYNCHOSPORIUM OF BARLEY**

Leaf blotch was at one of its highest ever levels in the 1999-2000 season. A large proportion of the samples came from cv. Regina, some crops of which had up to 50% of their flag leaf area infected. Several of the current winter barley cultivars carry the race specific resistance BRR-2. Cultivar Leonie, which has a NIAB disease rating of 9, carries BRR-5. Of the current NIAB Recommended List spring barleys, only cv. Pewter was resistant in the field.

- **NET BLOTCH OF BARLEY**

The higher than expected levels of net blotch on some crops of cv. Regina in 1998 and 1999 were not seen on crops of this cultivar, from which disease samples were received, in the year 2000. Winter barley cultivars inoculated with a mixture of isolates expressed a range of quantitative responses under glasshouse conditions. The spring barley County was resistant in similar tests.

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

32 infected samples were received in 2000, of which 20 contained BaYMV and 15 had BaMMV. One new outbreak of resistance-breaking BaYMV was reported from Oxfordshire (cv. Epic). A sample of spring barley from Lincolnshire received in early July from a crop sown in late March proved to have BaMMV: the first time that symptoms and virus have been found on a spring cultivar sown in the spring.

- **MILDEW OF OATS**

Mildew was at very low levels, particularly within the winter crop. Only race 5 (OMV-1,2,3), a widely virulent and common race, was identified.

- **CROWN RUST OF OATS**

Crown rust was more widespread than in recent years. Virulence to the winter oat cultivars Millennium and Viscount, identified in one isolate for the first time in 1999, was found in eleven isolates. The previously highly resistant spring oat cv. Sailor was susceptible to one isolate, identified as race 265.

WINTER CEREAL DISEASE SURVEYS, 2000

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 406 randomly selected fields of winter barley and 419 similarly selected fields of winter wheat were sampled as part of the 2000 national survey of cereal diseases. The total foliar disease recorded on the top two leaves of winter barley (10.3%) was less than in 1999 (12.1%) and 1998 (18.2%). However, leaf blotch remained the most severe and widespread of the barley foliar diseases, affecting on average 5.2% of the area of leaf 2 and being recorded in 93% crops from the stratified sample. This was the highest level recorded since 1983. Although less severe than in any survey since 1995, net blotch was the second most severe disease, affecting 65% of samples with 1.1% area leaf 2 affected. Brown rust, at 0.6% area of leaf 2 affected, was at its lowest severity recorded since 1996, when 0.1% area of leaf 2 was affected. Mildew was recorded less frequently than in 1999 and affected 0.6% of leaf 2 compared with 1.0% and 0.8% recorded in 1999 and 1998, respectively. Leaf spot and halo spot were recorded at trace levels and yellow rust was not recorded. The percentage tillers affected by moderate plus severe lesions of eyespot (17.9%), was the highest recorded since 1993. Of the winter wheat diseases, septoria leaf blotch was the most severe foliar disease for the tenth consecutive year, affecting 7.2% of the area of leaf 2 compared with 6.7% in 1999, 7.7% in 1998 and 3.1% in 1997. Septoria leaf blotch was also present at trace levels on the ears. Glume blotch was the next most common and severe foliar disease, being recorded in 48.5% of the stratified sample, and affecting an average of 0.3% area leaf 2 but occurring only at trace levels on leaf 1 and the ear. Brown rust levels, at 0.1% of the area of leaf 2, fell to those recorded in earlier surveys following the previous two years of high levels in 1998 and 1999 (0.3% and 0.7% on leaf 2 respectively). Mildew affected 0.1% of the area of leaf 2, which equalled the lowest ever level recorded in 1998. Yellow rust was recorded at trace levels on both leaves 1 and 2 but was absent from the ear. Moderate plus severe levels of eyespot were the highest recorded since stem base diseases were included in the survey in 1975. 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; 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 1999-2000 growing season, and includes information on fungicide use. The results are compared, where appropriate, with those from previous years.

METHODS

The 2000 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 1999 MAFF agricultural census. The distribution of farms between regions was proportional to the regional area of winter barley and wheat grown and to 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 406 fields of winter barley and 419 fields of winter wheat were randomly selected and sampled. Calculation of the national results, based on a stratification according to location and farm size resulted in utilisation of data from 343 and 336 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 the severity recorded in 1999 with 5.2% area leaf 2 affected (Table 2). It was the most widespread disease with 93% of samples affected nationally. Net blotch (*Pyrenophora teres*), at 1.1% area of leaf 2, was the second most severe and common disease although levels were lower for the second consecutive year (Fig. 1). Mildew (*Blumeria graminis*) was recorded less frequently and was less severe than in 1999, affecting 0.6% of leaf 2. Leaf spot (*Septoria* spp.) and halo spot (*Pseudoseptoria donacis*) were all recorded at trace levels and yellow rust was not recorded.

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

	Leaf 1	Leaf 2
Mildew	0.2	0.6
Brown rust	0.4	0.6
Net blotch	0.6	1.1
Leaf blotch	1.7	5.2
Leaf spot	tr	tr
Halo spot	tr	0.0
Yellow rust	0.0	0.0
Insect damage	0.5	0.6
Green leaf area	86.1	67.6

tr = trace (< 0.05)

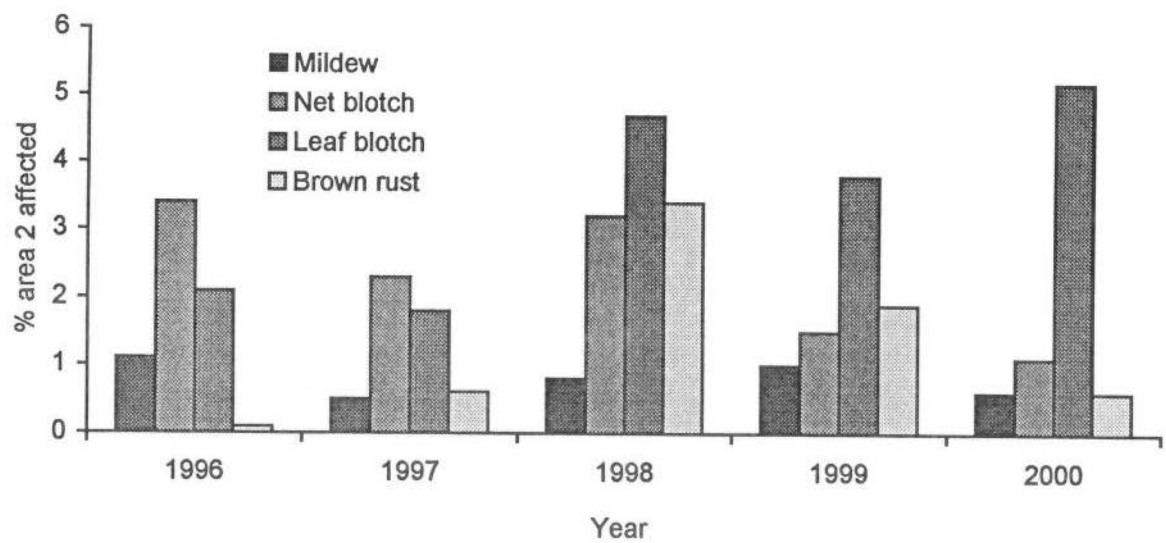

Fig 1 National foliar disease levels (mean % area leaf 2 affected)

Eyespot (*Pseudocercosporella herpotrichoides*) was recorded in 89% of crops, which was more frequently than in any survey since 1994 (92%). It was also more severe than in any survey since 1993 with 17.9% of stems affected by moderate and severe symptoms compared to 9.2% in 1999, 7.2% in 1998 and 9.1% in 1997. Sharp eyespot (*Rhizoctonia cerealis*) was recorded less frequently than in 1999, affecting 36% of crops sampled. Moderate and severe symptoms affected 2.0% of stems, slightly more than the 1.6% recorded in 1999. Symptoms of fusarium (*Fusarium* spp.) were present in 96% of crops, with moderate and severe levels on 12.0% of stems compared with 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	15.9	16.3	1.6
Sharp eyespot	2.2	1.7	0.3
Nodal fusarium	17.3	10.5	0.1
Internodal fusarium	7.0	1.8	0.2
All fusarium	20.0	11.7	0.3

Regional disease severity

The highest levels of mildew were recorded in Wales where Regina was the predominant cultivar (resistance rating 3, Anonymous, 1999). Net blotch was most severe in the East Midlands (1.4% area leaf 2 affected) and incidence was greatest in the Eastern region (74%). The severity of brown rust (*Puccinia hordei*) was highest in the North West and East Midlands regions, affecting an average of 1.1% area on leaf 2. Leaf blotch was most severe in the South West with 9.4% average area of leaf 2 affected, and least severe in the Eastern region (Table 4). Leaf blotch affected all samples from the North West and South East regions but incidence fell to 85% of samples from the Eastern region. Halo spot was only recorded at trace levels in the Yorkshire and the Humber region and Wales. Leaf spot occurred in all regions and was most prevalent and severe in the North West region. Yellow rust (*Puccinia striiformis)* was not recorded in any region.

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

Region	No. of samples	Mildew	Brown rust	Net blotch	Leaf blotch	Leaf spot	Halo spot	Yellow rust
NE	22	1.0	tr	0.9	4.7	tr	0.0	0.0
NW	13	0.5	1.1	1.3	4.1	0.3	0.0	0.0
Y & H	67	0.7	0.4	0.5	4.7	tr	tr	0.0
EM	58	0.5	1.1	1.4	4.5	tr	0.0	0.0
WM	43	0.9	0.3	0.7	6.2	tr	0.0	0.0
EAST	87	0.5	0.7	1.1	2.6	tr	0.0	0.0
SE	20	0.2	tr	1.3	5.6	0.0	0.0	0.0
SW	58	0.1	0.2	1.2	9.4	tr	0.0	0.0
WALES	30	2.4	0.4	1.0	6.2	tr	tr	0.0
National (stratified)	343	0.6	0.6	1.1	5.2	tr	0.0	0.0

The effect of cultivar on disease severity

As in 1999, Regina, Intro, and Fanfare were the three most commonly sampled cultivars in the survey, accounting for 39%, 9% and 8% of the national figure respectively. This represented an increase for Regina and a slight fall for the other two cultivars. Of the ten most common cultivars in the stratified sample the highest level of leaf blotch was recorded on Vertige at 9.0% of the area of leaf 2 (resistance rating 5). Brown rust was most severe on Heligan, affecting 2.8% area of leaf 2 (resistance rating 7). The highest net blotch levels were found on Angela with 2.2% area of leaf 2 affected (resistance rating 6) and the highest mildew levels were recorded on Hanna 5.4% area of leaf 2 (resistance rating 4) (Fig. 2).

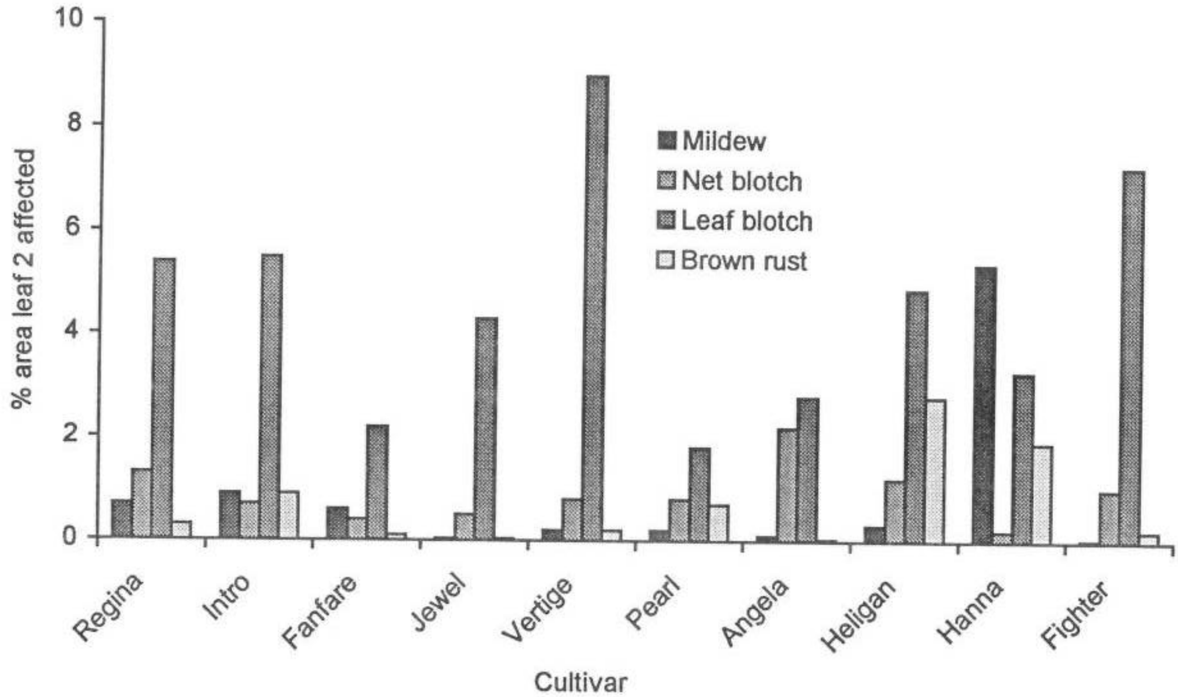

Fig 2 Foliar diseases on main cultivars (mean % area leaf 2)

The proportion of cultivars with a resistance rating of 5 or less (those considered to be susceptible to disease) for leaf blotch and net blotch increased from 1994 to 1995, with resistance to net blotch showing a greater fall from 1995 although in 2000 it showed a slight increase (Fig. 4). The fluctuation in the proportion of crops with low resistance rating does not accurately mirror those of the diseases.

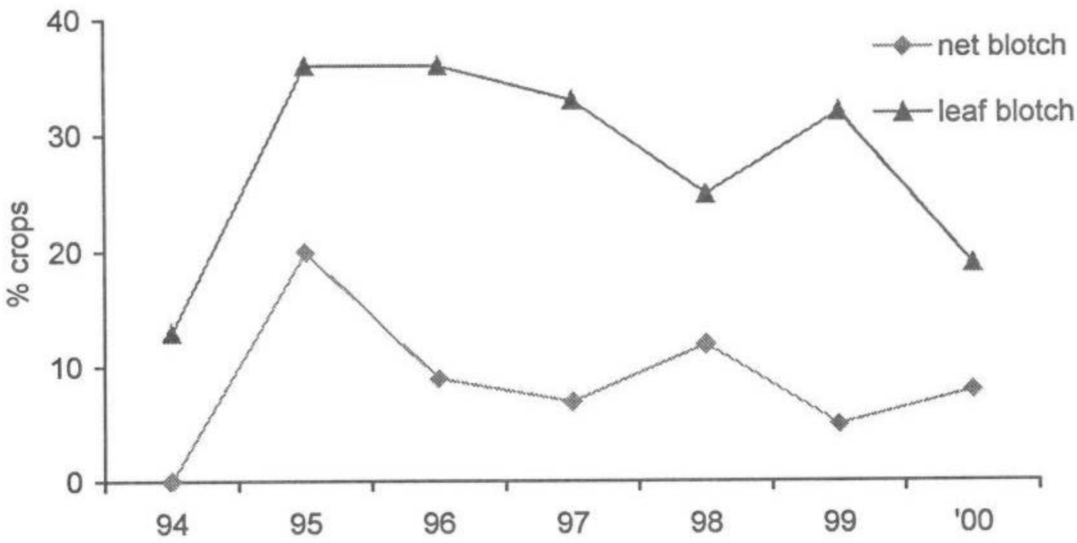

Fig 3 Percentage crops sown with a resistance rating of 5 and less for net blotch and leaf blotch

Sowing date and disease

Generally, foliar diseases were more severe in earlier drilled crops and leaf blotch more severe on crops drilled between 24 and 30 September. Eyespot and sharp eyespot were also more severe in crops drilled before 24 September and eyespot more damaging in crops following a cereal.

Fungicide use

Fungicide sprays were used on 95% of crops with a mean of 1.7 sprays per crop (compared with 95% and 1.6 in 1999). Six 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 66% at or after flag leaf emergence (GS 39). Thirty four per cent of crops received a single spray, 71% at *c.* GS 31. Fifty three per cent were sprayed twice, with the majority (82%) at GS 31 and the second spray at or after GS 37 (flag leaf emerging). Nine per cent of crops received three or more fungicide sprays, an increase of 2% when compared to the 1999 survey. The most commonly applied fungicide products were Amistar (263 applications), Opus (115 applications) Unix (97 applications), and Twist (50 applications). The number of different foliar applied fungicide products totalled 76 with 25 active ingredients. Seventy three per cent of crops in the survey were grown from certified seed, and 84% of all crops were known to be grown from fungicide treated seed with 6% 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 1999 and 1998, although septoria leaf blotch (*Septoria tritici*, teleomorph: *Mycosphaerella graminicola)* was more severe than in 1999, affecting 7.2% of the area of leaf 2 and was for the tenth consecutive year the most severe foliar disease. Glume blotch (*Stagonospora nodorum*, teleomorph: *Phaeosphaeria nodorum*) affected 0.3% of the area of the second leaf but only occurred at trace levels on leaf 1 and the ear (Table 5). Brown rust (*Puccinia recondita*) affected 0.1% of the area of leaf 2, a seven fold decrease from 1999. Mildew (*Blumeria graminis*) affected 0.1% of the area of leaf 2, and its incidence was the lowest since the surveys began in 1970 (Fig. 4). Yellow rust (*Puccinia graminis*) was recorded at trace levels on both leaves and *Didymella exitialis* at trace levels on leaf 2. Fusarium ear blight (*Fusarium* spp.) symptoms were recorded in 38% of samples compared with 33% in 1999, 61% in 1998, 22% in 1997 and 2% in 1996, making it the second highest incidence of ear blight in any survey since records began in 1987.

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

	Leaf 1	Leaf 2	Ear
Mildew	tr	0.1	0.1
Septoria leaf blotch	2.2	7.2	tr
Glume blotch	tr	0.3	tr
Yellow rust	tr	tr	0.0
Brown rust	0.1	0.1	-
Didymella	0.0	tr	-
Cephalosporium	0.0	0.0	-
Tan spot	0.0	0.0	-
Insect damage	1.1	0.8	-
Green leaf area	89.9	76.4	-

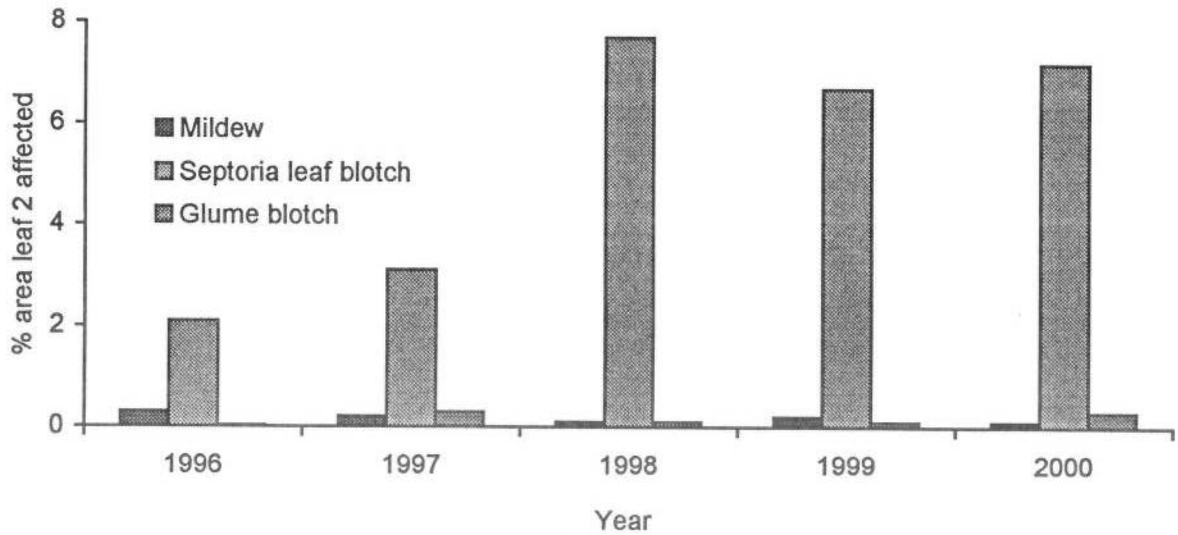

Fig 4 National foliar disease levels (mean % area leaf 2 affected), 1996-2000

Levels of eyespot, at 2.9% stems affected with moderate and severe symptoms, were higher than in 1999 (13.5%) (Table 6, Fig 5). Moderate and severe symptoms of sharp eyespot affected 3.1% of stems, fewer than recorded in the previous three surveys (4.6%, 4.6% and 4.2% of stems respectively) (Fig. 6). The fusarium complex affected 22.5% of stem bases which was higher than in 1999 (20.1%) (Table 6).

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

	Slight	Moderate	Severe
Eyespot	19.6	21.8	1.2
Sharp eyespot	4.2	2.9	0.2
Nodal fusarium	11.1	4.9	tr
Internodal fusarium	6.5	3.9	tr
All fusarium	14.5	7.9	0.1

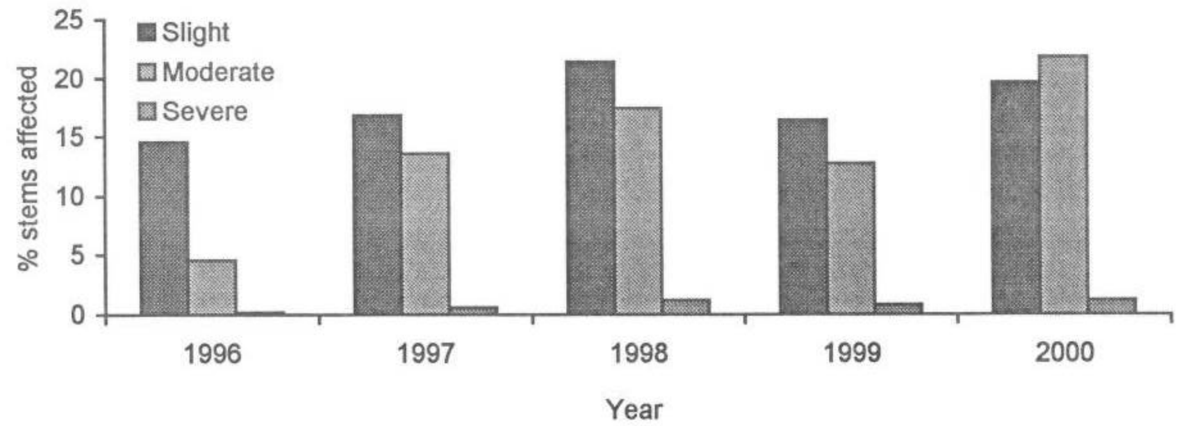

Fig 5 National levels of eyespot (mean % stems affected)

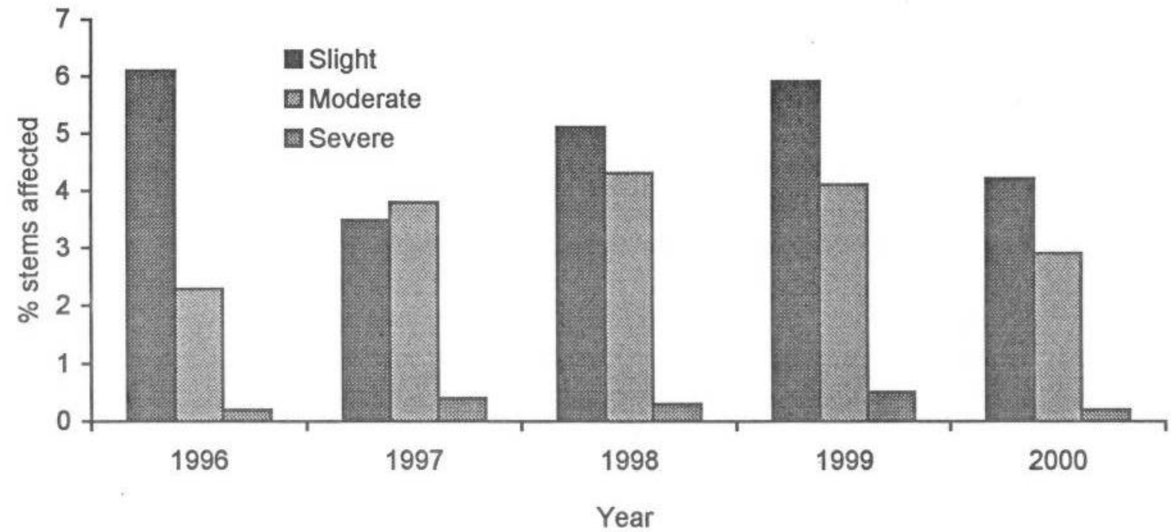

Fig 6 National levels of sharp eyespot (mean % stems affected)

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

Take-all was present in 32% of crops. Take-all patches were recorded in 11.5% of crops compared with 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 (1999)	225.0	68.0	30.0	9.0	3.0	110.0
Per cent of total (1999)	67.2	20.3	9.0	2.7	0.9	32.8
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

* 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 15% of crops with the majority 93% recorded as category 1 (a scattering of plants showing symptoms). The remaining 7% had small patches of BYDV. No crops were recorded as having symptoms which affected more than 10% of the field.

Regional disease incidence and severity

The highest levels of septoria leaf blotch were found in Wales, the South West and the North West regions and the lowest in the North East where the incidence of the disease was under 90%. It was recorded in every sample received from the North West, West Midlands, South East, South West and Wales, elsewhere incidence was above 90%. Glume blotch was recorded in all regions and the highest levels were in the Yorkshire & Humber region. Mildew levels were also higher in this region with an average of 0.3% of leaf 2 affected. Brown rust levels were low in all regions where it was recorded, apart from the East where it reached levels of 0.3% average area leaf 2 affected. Yellow rust was recorded in samples from the North East, Wales and the two midlands regions but only reached levels of 0.1% area of leaf 2 affected in the West Midlands (Table 9).

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

Region	No. of samples	Mildew	Septoria leaf blotch	Glume blotch	Yellow rust	Brown rust	*Didy -mella*	Tan spot	*Cephalo -sporium*
NE	18	tr	2.0	0.1	0.0	0.0	0.0	0.0	0.0
NW	8	0.1	10.6	0.8	0.0	0.0	0.0	0.0	0.0
Y&H	58	0.3	6.4	1.0	0.0	0.1	0.0	0.0	0.0
EM	80	0.1	4.2	0.2	tr	0.1	tr	0.0	0.0
WM	39	tr	6.2	0.2	0.1	0.0	0.0	0.0	0.0
EAST	103	0.1	8.1	0.3	0.0	0.3	tr	0.0	0.0
SE	36	tr	9.7	0.1	0.0	0.1	tr	0.0	0.0
SW	46	tr	11.2	0.2	0.0	0.0	tr	0.0	0.0
WALES	31	0.1	13.0	0.1	0.0	tr	tr	0.0	0.0
National (stratified)	336	0.1	7.2	0.3	tr	0.1	tr	0.0	0.0

Levels of moderate plus severe eyespot were highest in the North West region where incidence was 100%. Overall moderate plus severe levels were generally highest on samples from the midlands when compared with the north, east and south and west.

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

Effect of cultivar on disease severity

For the second successive year Consort, with 24% of crops, was the most commonly sampled cultivar in the survey. In second place was Claire at 19%, an increase from 3% in 1999. Madrigal showed the highest levels of septoria leaf blotch, with 15.4% area of leaf 2 affected followed by Equinox with 10.9% area of leaf 2 affected (both resistance rating 5). Mildew and glume blotch were most severe on Riband, with 0.6% area of leaf 2 affected (resistance rating 6) and 0.4% area of leaf 2 affected (resistance rating 5) respectively (Fig. 7).

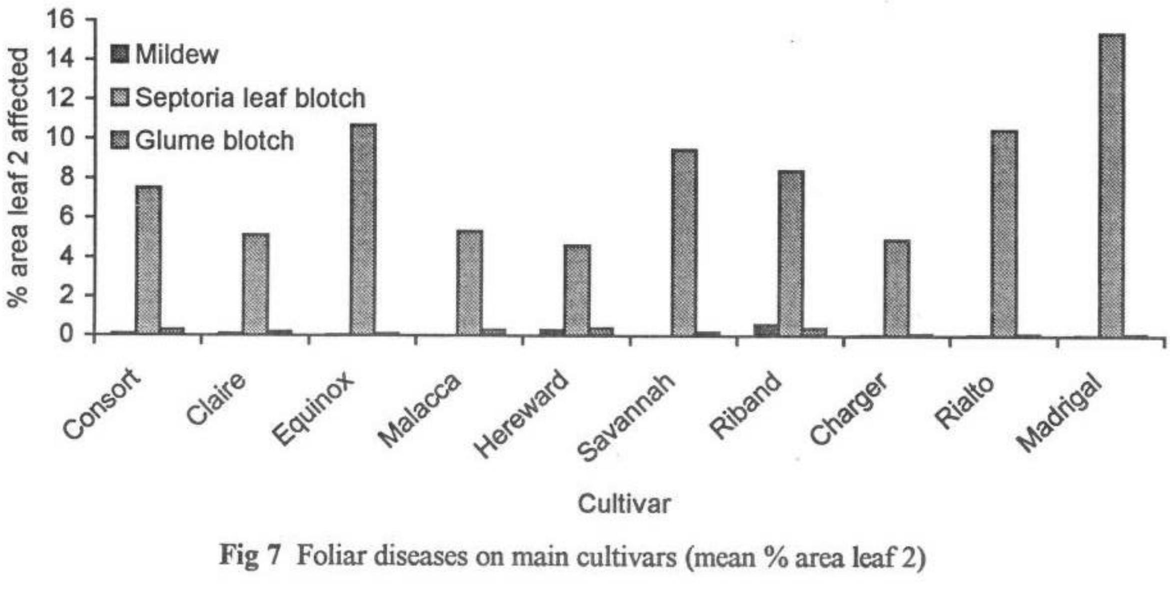

Fig 7 Foliar diseases on main cultivars (mean % area leaf 2)

The proportion of cultivars with a resistance rating of 5 or less (those considered to be suceptible to disease) for septoria leaf blotch and glume blotch was less than in 1999 and by contrast the proportion of mildew susceptible cultivars increased. This is probably a reflection of the increased area sown with Claire with a resistance rating for septoria leaf blotch and glume blotch of 7 and mildew rating of 4 (Fig. 8). As with winter barley, the fluctuation in the proportion of crops with low resistance rating does not accurately mirror those of the diseases.

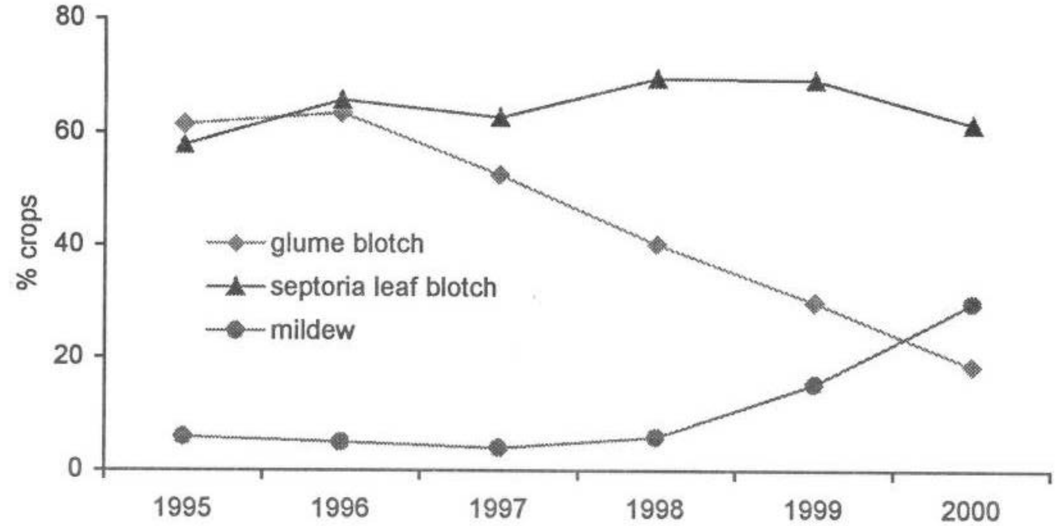

Fig 8 Percentage crops sown with a resistance rating of 5 and less for glume blotch, septoria leaf blotch and mildew

Previous cropping, sowing date and disease

As in past surveys the lowest levels of eyespot were found in crops following grass (4% of the stratified sample). Most crops followed a cereal or an oilseed rape crop (28% and 22% respectively). Sharp eyespot levels were most severe following other crops or pulse/legumes but least severe after grass. Moderate and severe levels of fusarium stem base diseases were also lowest following grass and highest after potatoes. Take-all patches were recorded on more crops following wheat than any other crop although the incidence of take-all was greatest after set-aside. Monoculture had no obvious influence on foliar disease severity and little effect on levels of either fusarium or sharp eyespot, but eyespot levels tended to be highest following one previous wheat crop and take-all levels were lower in first wheats. A non-cereal break of at least one year appeared to have reduced the levels of moderate and severe eyespot. Take-all symptoms were more prevalent in crops where no break had occurred. For the third successive year septoria leaf blotch was most severe on crops drilled in late October and eyespot less severe in crops drilled after October.

Fungicide use

Fungicide sprays were used on 98% of crops, with 91% receiving two or more treatments (99% and 89% in 1999 respectively). The most popular regime, applied to 31% of crops, was a two-spray programme with the first spray aimed at GS 31 and a second spray at GS 39. Thirty six per cent of crops received a three-spray programme. The most popular, applied to 24% of crops, was a first spray aimed at GS 31, followed by a second aimed at GS 39 and a third at GS 59. Crops received on average 2.5 fungicide spray applications (2.5 in 1999). The most commonly applied fungicide products were Amistar (217 applications), Landmark (185 applications), Opus (148 applications) and Folicur (107 applications). The number of different foliar applied fungicide products totalled 87 with 26 active ingredients. Seventy one per cent of crops were grown from certified seed with 92% of crops sown with fungicide treated seed and 5% of growers unable to specify seed treatments. Seventy four per cent of crops were treated with insecticides, the majority (85%) received a single spray mostly in the autumn (80%).

DISCUSSION

Overall the total severity of foliar diseases was lower than 1999 but the severity of the main foliar diseases of winter barley (leaf blotch) and of winter wheat (septoria leaf blotch) increased. Leaf blotch was at its highest severity since 1983 and septoria leaf blotch at its second highest since 1985.

Net blotch severity was lower than that of leaf blotch for the third successive year, so reversing a three-year trend where net blotch dominated. This reverse does not appear to be related to changes in the area of barley sown with cultivars with a greater degree of resistance to net blotch. However, the average difference in the proportion of susceptible cultivars grown between leaf blotch and net blotch for the last seven years has been 19% and this may account for the difference in severity between the two diseases. Mildew levels on wheat, were at their lowest since the survey began, despite the increase in the area of the cultivar Claire. This may be a reflection of the wet season suppressing infection and sporulation.

The severity of glume blotch of wheat was again low but showed signs of increasing, particularly in the north east part of England. In general, the severity of the diseases recorded is reflected in their epidemiology, with crops in the western half of the county having the highest incidence and severity of the 'wet weather diseases', such as leaf blotch, septoria leaf blotch and eyespot.

Damaging lesions of eyespot (the moderate and severe categories) were at their highest recorded in barley since 1983 and in wheat since the surveys began. Disease resistance to eyespot in winter wheat was not a major component of cultivars sown in 2000, with 60% of crops sown in 2000 with a resistance rating of 5. However, this compares with 93% in 1996. So some improvement is apparent. Spray applied at around GS 31 increased to 89% but only 14% contained an active ingredient effective against eyespot (eg cyprodinil, flusilazole and prochloraz).

There is obviously a major interaction between cultivar, weather and fungicide use (Hardwick *et al.*, 2000b). Results from the survey indicated that disease levels fluctuated irrespective of fungicide use and cultivar and it must be concluded that the weather has the most dominant effect. However, there are indications that cultivar resistance is more important in suppressing disease than fungicide use and cultivars should be selected with this fact in mind.

ACKNOWLEDGEMENT

The project was funded by MAFF.

REFERENCES

Anonymous (1999). UK recommended lists for Cereals 2000. Cambridge, UK: NIAB.

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., 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.

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 higher in 2000 than in 1998 and 1999. Virulence frequencies for Pm2, Pm4b and Pm6 were very high, due to considerable selection pressure from current cultivars carrying the corresponding resistance genes. Virulence for Pm8 remained high, despite a decrease in the area of corresponding resistance. The mildew population remained homogeneous, with one predominant pathotype – V2,4b,5,6,8,Ta2 – present in 61% of isolates and able to infect cultivars accounting for nearly three-quarters of the winter wheat area. 16 of the 18 2001 Recommended winter wheat cultivars are potentially susceptible to at least 97% of mildew isolates, although this is offset by effective partial resistance in many important cultivars. Recent new cultivars are generally mildew-susceptible, carrying no effective specific resistance genes, with the possible exception of Shamrock. 3 out of 123 bulk isolates tested were insensitive to strobilurin fungicides.

INTRODUCTION

Powdery mildew levels in wheat were higher in 2000 than in the previous two years, facilitating collection of suitable samples. This may have been due to mild winter weather allowing successful survival of the pathogen, *Blumeria graminis* f sp *tritici*, and to subsequent spring and summer conditions being conducive to disease development. Also, the currently most popular winter wheat cultivars tend to be susceptible to mildew.

METHODS

202 samples were collected from winter wheat cultivars in 2000, the highest number for three years. Single colony isolates were successfully recovered from 163 samples, while two samples were tested as bulk populations. The source cultivars of the tested isolates are given below:

Winter cultivars	No. of isolates		No. of isolates		No. of isolates
Option	19	Cockpit	12	Riband	9
Oxbow	18	Shamrock	12	Hereward	8
Tanker	17	Soissons	12	Buchan	7
Biscay	16	Genghis	11	Consort	7
Deben	15	Madrigal	11	Malacca	7
Claire	14	Savannah	11	Reaper	7
Equinox	14	Eclipse	10	Aardvark	3
Rialto	14	Charger	9	ExSept	2
Buster	12	Napier	9		

The samples were collected from the following locations:

	No. of isolates		No. of isolates
Morley, Norfolk	68	Mepal, Cambs.	8
NIAB, Cambridge	55	Spalding, Lincs.	8
Headley Hall, N Yorks.	52	Gwent, S Wales	2
Wye, Kent	41	Saxham, Suffolk	2
Harper Adams, Shropshire	30	Woolpit, Suffolk	2
Bridgets, Hants.	18		
Total			**286**

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

Table 1 Differential cultivars used to determine virulence factors in isolates of wheat powdery mildew, 2000.

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	? Pm2, Pm3d + MlTo	*? Pm2, Pm3d* + Unknown
Broom	MlBr	*? Pm3d*
Sicco	Pm5, MlSi2	*Pm5*, Unknown
Wembley	MlSo	Unknown
Axona	MlAx	Unknown
Soissons	MlSs*	Unknown
Aardvark	Mld (+ Pm8?)	Mld *(+ Pm8?)*
Shamrock	?	?

* tentative designation for specific resistance factor

RESULTS AND DISCUSSION

Virulence frequencies

Virulence for Pm2, Pm4b and Pm6 was again detected in the majority of isolates tested (Table 2). Selection pressure continues to be high for these virulence genes, as they correspond to the resistance genes carried by cultivars comprising over half of the winter wheat area. Virulence for Pm8 remained high in the population, although the corresponding area with resistance has decreased over the last few years. V5 and VTa2 continue to maintain an almost maximum frequency, despite the absence of significant current selection.

Table 2 Frequency of wheat mildew virulence factors, 1993-2000, and 2000 areas of cultivars with the corresponding resistance.

	Frequency of virulence factors (%)								% area
Virulence factor	1993	1994	1995	1996	1997	1998	1999	2000	2000*
2	98	99	99	100	100	100	100	100	52
3b	-	-	4	3	4	1	2	1	0
4b	79	84	88	93	98	100	99	99	68
5	95	92	92	93	95	88	91	88	<1
6	78	80	89	96	99	100	100	99	54
8	93	93	95	96	98	97	99	97	20
17	-	-	10	15	16	8	22	2	0
d	15	20	19	33	26	18	6	12	<1
2,Ta2	80	82	85	92	93	86	97	96	<1
To	18	24	18	29	29	16	16	5	<1
Br	20	27	21	32	30	16	15	8	0
5,Si2	39	26	22	32	21	17	20	8	0
So	22	21	10	15	15	10	6	4	0
Ax	10	14	11	24	20	7	1	1	<1
Soissons						65	57	74	3
Number of isolates tested	356	347	265	313	328	187	148	286	

* NIAB (2000)

There appears to have been a reduction in the frequency of V17. However, there has previously been some doubt about the accuracy of detached leaf tests for the identification of this virulence gene, as field experience suggests that the virulence is very uncommon. Although some isolates give either clear virulent or avirulent reactions, many show inconsistent intermediate reactions.

There was a slight rise in the level of virulence for Mld which was not obviously related to increasing selection. The corresponding resistance is carried only by Aardvark, and possibly

Cadenza, which are not widely grown. Virulence for Axona remained low: there has been little selection for this factor since the decrease in popularity of Cadenza. The reduction in the levels of virulence for MlTo, MlBr and MlSi2 was also related to the absence of significant selection, as no currently popular winter wheat cultivars carry the corresponding resistance.

There appears to have been an increase in the frequency of virulence for Soissons. However, accurate identification of VSs is sometimes difficult: many isolates show intermediate reactions on detached leaves, although others give clear virulent or avirulent reactions. Thus, Soissons appears to possess specific resistance and a high level of non-specific resistance, giving a resistance rating of 8.

Frequency of pathotypes

The wheat mildew population continues to become more homogeneous. The predominant pathotype was again V2,4b,5,6,8,Ta2, present in 61% of the isolates tested (Table 3). This pathotype is capable of infecting cultivars comprising 73% of the winter wheat area. 37 different pathotypes were identified in 2000: a further measure of the decreasing variability of the population, as sample numbers were higher in 2000. This trend has been apparent over the last 5-6 years and is in direct contrast to that for the barley mildew population, which continues to be increasingly heterogeneous (Slater & Clarkson, 2000).

Table 3 Frequencies of the most commonly identified pathotypes, 1993-2000, as defined by the factors in Table 1, with the exception of MlSs (Soissons).

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

Complexity of isolates

There was little change in the complexity of the wheat mildew population. The majority of isolates tested in 2000 carried 6 virulence factors, corresponding to the predominant pathotype V2,4b,5,6,8,Ta2 (Table 4). As the population continues to be dominated by this single pathotype, isolates with more or less than 6 factors are becoming increasingly uncommon.

Table 4 Number of virulence factors in the wheat mildew population, 1997-2000.

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

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

Infection of winter wheat cultivars

The majority of the current winter wheat Recommended List cultivars are potentially susceptible to at least 97% of mildew isolates (Table 5). However, most of the commonly grown cultivars exhibit moderate levels of partial resistance. For example, Savannah has a high level of partial resistance, with a resistance rating of 8, although its specific resistance genes are matched by 97% of the population. Shamrock, first recommended in 1999, also appears to be resistant but this may be due to a low incidence of virulence corresponding to the specific resistance factor of this new cultivar. If the frequency of specific virulence increases, the effect of partial resistance may then become more apparent.

Continued monitoring of virulence associated with seemingly resistant cultivars is therefore essential to detect increasing levels of virulence and potential breakdown of resistance as early as possible.

Table 5 Proportion of mildew isolates able to infect winter wheat cultivars in Recommended List trials (2001 Recommended List cultivars in **bold**; mildew resistance ratings in brackets).

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Charger (7)	100	**Buchan (6)**	97
Eclipse (7)	100	**Equinox (5)**	97
Hereward (6)	100	Genghis (6)	97
Rialto (6)	100	**Madrigal (6)**	97
Biscay (5)	99	**Napier (6)**	97
Buster (4)	99	**Option (4)**	97
Claire (4)	99	Oxbow (6)	97
Cockpit (5)	99	**Savannah (8)**	97
Consort (6)	99	**Tanker (7)**	97
Deben (5)	99	**Soissons (8)**	74
Malacca (7)	99	Aardvark (8)	12
Reaper (6)	99	**Shamrock (8)**	4
Riband (6)	99		

Resistance factors in wheat cultivars

The resistance genes/factors identified in new and existing cultivars from laboratory tests are shown in Table 6.

Table 6 Specific mildew resistance factors in winter wheat cultivars (2001 Recommended List cultivars in **bold**)

None	*Pm2,4b,6*	*Pm4b,Pm6,Pm8 (Pm2?)*	*MlSs*
Charger	**Biscay***	**Buchan**	**Soissons**
Eclipse	**Consort**	**Napier#**	
Hereward	**Deben***	Oxbow	*Mld(Pm8?)*
Rialto	**Malacca**	**Savannah**	Aardvark
	Riband		
Pm2,Pm4b		*Pm5,MlTa2*	*Unknown*
Claire	*Pm6,Pm8*	Mercia	**Shamrock**
	Genghis		
Pm2,6	**Madrigal**	*MlTo*	
Abbot	**Tanker***	Spark	
Buster			
Cockpit	*Pm2,Pm4b(Pm6,Pm8?)*		
Reaper	**Option***		

newly Recommended in 2000.

* newly Recommended in 2001.

No new resistance factors or combinations were identified in the 2000 Survey. As in the previous two years, all isolates with virulence for Aardvark carried Vd. It seems likely, therefore, that Aardvark carries the resistance factor Mld.

The newly recommended cultivars Biscay, Deben, Option and Tanker all carry common resistance combinations already matched by high levels of specific virulence in the pathogen population.

Fungicide resistance tests

123 bulk isolates of wheat powdery mildew were tested for sensitivity to strobilurin fungicides by inoculation onto leaves treated with 512 ppm azoxystrobin; known sensitive isolates were also included. Three isolates exhibited insensitivity to azoxystrobin and were further tested at a range of azoxystrobin rates, together with three 1999 strobilurin-insensitive isolates and sensitive controls. The three 2000 isolates appeared to be more sensitive than the three 1999 isolates but were considerably less sensitive than the sensitive control isolates.

REFERENCES

Clarkson, J D S & Slater, S E (2000). Mildew of Wheat. *UK Cereal Pathogen Virulence Survey 1999 Annual Report,* pp 22-28.

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 (2000). Seed Production, Issue No. 22, November 2000.

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

YELLOW RUST OF WHEAT

R A BAYLES and P L STIGWOOD

NIAB, Huntingdon Road, Cambridge CB3 0LE

Yellow rust was widespread in 2000 for the fourth consecutive year. 96% of isolates tested carried virulence for WYR17 and 28% possessed virulence for WYR6,17. Isolates with combined virulence for WYR6 and WYR17 were widely distributed throughout England. Isolates capable of overcoming the resistance of the cultivar Oxbow were detected for the first time. These isolates carried the virulence combination WYV1,2,3,4,9,17,CV together with virulence for Oxbow.

2000 VIRULENCE SURVEY

The resistant cultivars, Consort, Malacca, Claire and Charger accounted for just over half the winter wheat acreage (53.4%) in 2000, an increase of 19.7% on 1999. The area of WYR17 cultivars decreased from 25.2% in 1999 to 18.5 % in 2000. The area of WYR6,17 cultivars also decreased from 11% in 1999 to 9.6% in 2000.

Table 1 Popularity of winter wheat cultivars, 2000
(from seed certification statistics for England and Wales)

Cultivar	WYR Factors	NIAB Resistance Rating(1-9)	% acreage
Consort	?R	9	26.1
Claire	R	9	15.0
Malacca	R	9	8.2
Hereward	CV+	7	6.8
Savannah	9,17	5	6.8
Equinox	6,9,17	6	6.2
Riband	13	6	5.6
Rialto	6,9	6	4.3
Charger	? 6 + APR	9	4.1
Madrigal	6,9,17	3	2.8
Soissons	3	8	2.9
Reaper	17	4	1.2
Napier	6,9,17	4	0.6

Table 2 Cultivars from which isolates were collected in 2000

Cultivar	WYR factors	Number of isolates
Biscay	17	10
Claire	R	5
Oxbow	?(9,17,CV)	5
Madrigal	6,9,17	4
Napier	6,9,17	4
Tanker	9	4
Savannah	9,17	3
Equinox	6,9,17	3
Consort	R	3
Cockpit	17	2
Genghis	6,9,17	2
Deben	R	1
Hereward	CV+	1
3 others	-	3

50 isolates of *Puccinia striiformis* were tested in seedling virulence tests. These were obtained from 16 different cultivars (Table 2), mainly of the WYR17 type.

A new pathotype virulent on the previously resistant variety Oxbow was identified. This possessed the virulence combination WYV1,2,3,4,9,17,CV (+ virulence for Oxbow). This is the first time that virulence for Carstens V (CV) has been found in combination with virulences WYV9 and/or WYV17. This pathotype was identified in three counties (Norfolk, Cambs, Lincs), and originated mainly from cultivar Oxbow, although it was also found on Hereward and Consort in Lincolnshire. Observations indicated that Oxbow was severely infected in the field.

Isolates from WYR6,9,17 cultivars, Napier, Madrigal, Equinox, and Genghis, accounted for 26% of the total received, the same proportion as in 1999. These came from widely dispersed regions of England (including Kent, Hampshire, Lincolnshire, Northumberland and East Anglia).

Table 3 Seedling reactions of winter wheat RL candidates and other cultivars to selected isolates with and without virulence for cultivar Oxbow

		Isolate:	00/1	00/2	00/32	00/40	00/41
		Cultivar:	Consort	Claire	Napier	Oxbow	Oxbow
		Location:	Kent	Norfolk	Northumb	Cambs	Lincs
		Virulence:	1,2,3,6	1,2,3,6,7	1,2,3,4,6,9,17	1,2,3,4,9,17,CV	1,2,3,4,9,17, CV
Cultivar	RL status	WYR			Seedling reaction		
Storm	RL 1	9,17	R	R	S	S	S
Access	RL 1	6,9,17	R	R	S	R	R
Phlebas	RL 1	6,9,17	R	R	S	R	R
Chatsworth	RL 1	R	R	R	R	R	R
Richmond	RL 1	R	R	R	R	R	R
Macro	RL 1	R	R	R	R	R	R
Solstice	RL 1	R	R	R	R	R	R
X119	RL 1	R	R	R	R	R	R
CPBT W64	RL 1	Rx	S	R	R	R	R
Claire	G	Rx	S	I	R	R	I
Consort	G	Rx	R	R	R	S	S
Deben	PG	Rx	S	I	S	S	R
Option	PG	R	R	R	R	R	R
Tanker	PG	9	R	R	S	I	S
VPM 1	-	17	R	R	S	S	S
Savannah	G	9,17	R	R	S	S	S
Carstens V	-	CV	R	R	R	S	S
Hereward	G	CV+	R	R	R	S	S
Oxbow	-	?(9,17,CV)	R	R	R	S	S

Key to seedling reactions: R= resistant (average reaction type 0-2)
I = intermediate (average reaction type 2.1-2.9)
S= susceptible (average reaction type 3-4)

Table 3 shows seedling reactions of winter wheat RL candidates and other cultivars to two isolates of the new pathotype (00/40 and 00/41) and three other isolates from the 2000 survey. Of the RL1 candidates, only Storm was susceptible to isolates 00/40 or 00/41 and this cultivar was also susceptible to 00/32 and can be grouped as a WYR9,17 cultivar. Access & Phlebas were susceptible to isolate 00/32 (WYV6,9,17) and resistant to the other isolates and can therefore be grouped as WYR6,9,17 cultivars on the basis of their seedling reactions. Access has a NIAB resistance rating of 4 (moderately susceptible) and Phlebas has a rating of 8 (resistant).

The five candidates that were seedling resistant to all isolates have resistance ratings of 9 (resistant).

Table 4 Differential cultivars used in seedling virulence tests in 2000 (Differentials shown in italics were omitted)

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

* Oxbow & Consort were added to seedling tests of the isolates found on Oxbow, Consort and Hereward, only after the new pathotype, WYV1,2,3,4,9,17,CV,(Oxbow) had been detected.

Isolates were tested for virulence on seedlings of the differential cultivars listed in Table 4, using methods described by Priestley, Bayles and Thomas, 1984.

Table 5 Virulence factor frequency (%)

Virulence Factor	87	88	89	90	91	92	93	94	95	96	97	98	99	00
WYV 1	87	68	62	85	91	88	89	65	90	97	100	99	99	100
WYV 2	100	100	100	100	100	100	98	100	99	97	100	99	99	100
WYV 3	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 4	47	78	97	91	86	86	89	86	67	59	47	79	87	90
WYV 6	89	72	57	69	64	88	68	41	35	16	1	7	21	32
WYV 7	8	6	2	9	19	7	8	4	0	3	7	4	10	4
WYV 8	*	*	*	*	0	0	0	0	0	0	0	0	0	0
WYV 9	5	66	99	94	88	76	84	94	95	97	99	99	99	96
WYV10														0
WYV15														0
WYV17									57	84	99	99	100	96
CV								75	55	9	13	1	4	16
YrA+												84	91	88
So												78	91	90
Sd												100	98	100
Sp												0	0	0
Parade							3	0	0	0	0	0	0	0
Madrigal										0	1	6	19	28
No. of isolates	52	71	156	67	42	77	63	49	83	32	138	94	97	50

Seedling virulence frequencies are given in Table 5. The frequencies of WYV1, WYV2, WYV3 were 100%. The frequency of WYV4 remained at a similar level to 1999. WYV6 increased by 11%, reflecting the fact that WYV6,17 had become more widespread in the UK population. WYV7 decreased slightly.

The frequencies of WYV9 and WYV17 were nearly 100%, as in 1999.

Virulence for Carstens V (CV) rose by 12% in 2000, reflecting its presence in the new pathotype virulent on Oxbow.

Virulence for YrA+, So and Sd were detected at high frequencies. No virulence for Sp , Parade, WYV10 and WYV15 was detected.

Virulence for Madrigal (WYR6,9,17) continued to increase in 2000, reflecting the widespread distribution of WYV6,9,17 throughout England. This was in spite of the fact that the total area of WYR6,17 cultivars decreased slightly in 2000.

Virulence for Oxbow was detected for the first time in eight isolates. Seven of these isolates were also virulent on seedlings of Consort, which had previously been susceptible to some Carstens V isolates. Oxbow virulent isolates will be examined in adult plant tests during the 2001 season.

Table 6 Pathotype frequencies (%) in 1999 and 2000

	frequency %	
Pathotype	**1999**	**2000**
WYV1,2,3,9,17,A+,Sd	10	4
WYV1,2,3,4,9,17,A+,So,Sd	57	58
WYV1,2,3,6,9,17,A+,Sd	2	4
WYV1,2,3,4,6,9,17,A+,So,Sd	16	24
WYV1,2,3,4,7,9,17,A+,So,Sd	9	2
WYV1,2,3,4,6,7,9,17,A+,So,Sd	2	0
WYV1,2,3,4,9,17,CV,(Ox),A+,So,Sd	0	16
WYV1,2,3,4,9,17,CV,A+,So,Sd	(2)*	0
WYV1,2,3,4,7,9,17,CV,A+,So,Sd	(1)*	0
WYV3,4,6,17,CV,A+,So,Sd	(1)*	0
WYV1,2,3,6,A+,Sd	0	2
WYV1,2,3,6,7,A+,Sd	0	2

* further tests in 2000 did not confirm the presence of CV virulence in these pathotypes

The most common pathotypes were WYV1,2,3,4,9,17,A+,So,Sd (58% compared to 57% in 1999), WYV1,2,3,4,6,9,17,A+,So,Sd (24% compared to 16% in 1999), and WYV1,2,3,4,9,17,CV,A+,So,Sd, (Oxbow), (16% compared with 0% in 1999).

Two relatively simple pathotypes, WYV1,2,3,6 and WYV1,2,3,6,7 were identified. These originated from juvenile crops of Consort and Claire, respectively, during the winter. These pathotypes were common in the 1980s but will be examined in adult plant tests in 2001 to see if they have any additional virulence for adult plants of Consort and Claire.

ADULT PLANT TESTS

12 isolates from the 1999 survey were tested for virulence on adult plants of 31 cultivars in polythene tunnels and on seedlings of the same cultivars (Table 7). The isolates were chosen on the basis of their seedling virulence phenotypes, the cultivars from which they had been collected and the location from which they originated.

All twelve isolates carried the WYV17 virulence. Five isolates collected from the resistant cultivar Claire, 99/47, 99/50, 99/105, 99/110 and 99/114, failed to infect adult plants of the cultivar. All five isolates had been sampled from crops or plots at adult plant stages, two being taken from infected ears.

Table 7 Adult plant tests in polythene tunnels 2000 (% leaf area infected with yellow rust, mean of 3 assessments, with seedling reactions shown in brackets)

	Isolate:	99/52	99/44	99/47	99/88	99/105	99/107
	source	Malacca Kent	Charger Kent	Claire Lincs	Malacca Northumb	Claire Cambs	Hereward Cambs
	Seedling virulence:	1,2,3, 9,17	1,2,3,4, 9,17	1,2,3,4, 9,17	1,2,3,4, 9,17	1,2,3,4, 9,17	1,2,3,4, 9,17
Cultivar	WYR						
Cockpit	17	20 (S)	24 (S)	17 (S)	13 (S)	35 (S)	13 (S)
Reaper	17	10 (S)	12 (S)	16 (S)	13 (S)	25 (S)	8 (S)
Buchan	9,17	16 (S)	15 (S)	12 (S)	6 (S)	27 (S)	10 (S)
Savannah	9,17	7 (S)	7 (S)	5 (S)	10 (S)	20 (S)	6 (S)
Biscay	9,17	2 (S)	6 (S)	1 (S)	0 (S)	8 (S)	17 (S)
Aardvark	6,17	0 (R)	0 (R)	1 (R)	0 (R)	0 (R)	0 (R)
Equinox	6,17	1 (R)	0 (R)	0 (R)	0(R)	0 (R)	0 (R)
Madrigal	6,9,17	10 (R)	2 (R)	0 (R)	0 (R)	0 (R)	1 (R)
Napier	6,9,17	2 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Genghis	6,9,17	1 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Eclipse	6,9,17	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Rialto	6,9	4 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Tanker	9	6 (S)	6 (S)	5 (S)	7 (S)	15 (S)	1 (S)
Hereward	CV+	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Shamrock	CV	0 (R)	0 (I)	0 (R)	0 (R)	0 (R)	0 (R)
Carstens V	CV	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Oxbow	?(9,17,CV)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Consort	Rx	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Deben	Rx + APR	0 (S)	0 (S)	0 (S)	0 (S)	0 (S)	0 (I)
Claire	Rx + APR	0 (S)	0 (S)	0 (S)	0 (S)	0 (S)	0 (S)
Malacca	Rx +APR	1 (S)	0 (S)	0 (S)	0 (I)	0 (R)	0 (S)
Apostle	2,6,+APR	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Charger	?6+APR	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Buster	R	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Cadenza	R	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Option	R	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Brock	7,14	0 (R)	0 (I)	0 (R)	0 (R)	0 (R)	0 (R)
Hobbit	14	2 (S)	10 (S)	4 (S)	4 (S)	21 (S)	0 (S)
Riband	13	5 (S)	7 (S)	3 (S)	5 (S)	5 (S)	5 (S)
Soissons	0	1 (S)	3 (S)	1 (S)	0 (S)	1 (S)	0 (S)

Highlighting indicates variety x isolate interactions in adult plant tests

Seedling reactions: R= resistant (average reaction type 0-2); I = intermediate (average reaction type 2.1-2.9); S= susceptible (average reaction type 3-4)

Table 7 contd Adult plant tests in polythene tunnels 2000 (% leaf area infected with yellow rust, mean of 3 assessments, with seedling reactions shown in brackets)

	Isolate: source: Seedling virulence	99/110 Claire Lincs 1,2,3,4, 9,17	99/112 Cockpit Scotland 1,2,3,4, 9,17	99/114 Claire Yorkshire 1,2,3,4, 9,17	99/50 Claire Kent 1,2,3,4,7, 9,17	99/85 Axona Suffolk 1,2,3,4,6, 9,17	99/102 Napier Lincs 1,2,3,4,6, 9,17
Cultivar	WYR						
Cockpit	17	14 (S)	9 (S)	10 (S)	8 (S)	14 (S)	8 (S)
Reaper	17	6 (S)	7 (S)	5 (S)	13 (S)	12 (S)	11 (S)
Buchan	9,17	17 (S)	9 (S)	8 (S)	13 (S)	12 (S)	4 (S)
Savannah	9,17	6 (S)	9 (S)	4 (S)	9 (S)	7 (S)	1 (S)
Biscay	9,17	1 (S)	1 (S)	5 (S)	0 (S)	2 (S)	6 (S)
Aardvark	6,17	0 (R)	0 (R)	0 (R)	0 (R)	2 (S)	0 (S)
Equinox	6,17	0 (R)	0 (R)	1 (R)	0 (R)	14 (S)	4 (S)
Madrigal	6,9,17	3 (R)	2 (R)	7 (R)	4 (R)	19 (S)	19 (S)
Napier	6,9,17	0 (R)	0 (R)	0 (R)	0 (R)	2 (S)	2 (S)
Genghis	6,9,17	0 (R)	0 (R)	5 (R)	0 (R)	11 (S)	2 (S)
Eclipse	6,9,17	0 (R)	0 (R)	0 (R)	0 (R)	1 (S)	0 (S)
Rialto	6,9	1 (R)	3 (R)	0 (R)	13 (R)	12 (S)	10 (S)
Tanker	9	2 (S)	3 (S)	7 (S)	1 (S)	6 (S)	4 (S)
Hereward	CV+	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Shamrock	CV	0 (I)	0 (R)	0 (R)	0 (I)	0 (R)	0 (R)
Carstens V	CV	0 (I)	0 (R)	0 (R)	0 (I)	0 (R)	0 (R)
Oxbow	?(9,17,CV)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Consort	Rx	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Deben	Rx + APR	0 (S)	0 (S)	0 (S)	0 (S)	0 (S)	0 (S)
Claire	Rx + APR	0 (S)	0 (S)	0 (S)	0 (S)	0 (S)	0 (S)
Malacca	Rx +APR	0 (I)	0 (S)	0 (R)	0 (S)	0 (S)	0 (S)
Apostle	2,6,+APR	0 (R)	0 (R)	0 (R)	0 (R)	0 (I)	0 (I)
Charger	?6+APR	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (I)
Buster	R	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Cadenza	R	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Option	R	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)	0 (R)
Brock	7,14	0 (R)	0 (R)	0 (R)	7 (R)	0 (R)	0 (R)
Hobbit	14	3 (S)	2 (S)	6 (S)	1 (S)	4 (S)	0 (S)
Riband	13	5 (S)	0 (S)	7 (S)	4 (S)	1 (S)	1 (S)
Soissons	0	0 (S)	1 (S)	0 (S)	1 (S)	1 (S)	0 (S)

Highlighting indicates variety x isolate interactions in adult plant tests
Seedling reactions: R= resistant (average reaction type 0-2); I = intermediate (average reaction type 2.1-2.9); S= susceptible (average reaction type 3-4)

Other isolates from resistant cultivars showed no infection on adult plants of those source cultivars. These were isolates 99/44 (Charger), 99/52 (Malacca), and 99/88 (Malacca).

Isolate 99/50, infected Brock (WYR7,14) and the WYR17/WYR9,17 cultivars confirming the virulence combination of WYV7,9,17 identified in seedling tests..

Levels of infection on Riband (WYR13) and Hobbit (WYR14) were generally low but nine isolates appeared to possess WYV 13 and seven isolates WYV14.

Nine cultivars with effective adult plant resistance (Deben, Claire, Malacca, Apostle, Charger, Buster, Cadenza, Option, Consort) maintained their resistance to all twelve isolates. Deben and Option were added to the Recommended List in 2000. Oxbow also showed resistance to all 1999 isolates, but its susceptibility to the new virulent pathotype will be closely monitored in 2001.

Cultivars Claire, Deben and Malacca, are susceptible as seedlings to many isolates, but have effective adult plant resistance.

REFERENCE

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

BROWN RUST OF WHEAT

E R L JONES

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

WBV-7 was found at increased frequency. The majority of isolates combined WBV-7 with WBV-1 and WBV-2. The newly introduced wheat cvs, Access, Macro, Tanker, Biscay and Phlebas, were seedling resistant. Field isolation nurseries identified high levels of resistance in cultivars postulated as carrying Lr gene 37 when this was combined with Lr genes 10 and/or 26. A number of other wheats were also resistant. Resistance conferred by Lr genes 9, 19, 24 and 28 remained effective against the UK pathotypes as was Lr37 in adult plant tests.

GLASSHOUSE SEEDLING TESTS WITH YEAR 2000 ISOLATES

Of the wheat brown rust samples received in year 2000, twenty were from winter wheats, seven from spring wheats and one was of unknown origin. The geographic origins of the samples are given in Table 1.

Table 1 Geographic origins of wheat brown rust samples, 2000

Location (county)	Number of samples
Cambs	16
Lincs	5
North Yorks	5
Suffolk	1
Unknown	1

Isolates of *Puccinia recondita* were cultured from 23 leaf samples and tested on three sets of wheat lines: 1) Differential cvs which comprised the standard WBR cvs (Table 2). 2) the core differential set (agreed amongst European leaf rust workers) of 'Thatcher' Near Isogenic Lines (NILs) carrying different Lr resistance factors (Table 3). 3) a number of newly introduced winter and spring wheat cvs (Table 4).

Table 2 Cultivars* used in tests with 2000 isolates

Cultivar	WBR-factor	Lr gene
Clement	1	26
Fundin	2	14a
Sappo	3	20
Halberd	4	20
Sterna	7	3

*The standard 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

Table 4 Newly introduced winter and spring* wheat cultivars included in tests with isolates from the 2000 survey

Solstice	Deben	CPBT W64
Access	Tanker	Chatsworth
Macro	Biscay	*Morph
Oxbow	XI19	*Wallace
Option	Storm	*Ashby
Phlebas	Richmond	

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 cultivars with temperature-sensitive resistance factors, interactions were classified as susceptible only if that reaction was expressed at both temperatures. The virulence combinations identified, based on the reactions of the standard differential cvs carrying known resistance factors, are given in Table 5. Their frequencies are compared with those from previous years (Table 5). There was an increase in frequency of combined virulences 1, 2 and 7, associated with greatly increased frequency of WBV-7 (Table 6) in the year 2000 isolates. Until now, WBV-7 virulence has remained at low frequency in the pathogen population since it was first identified in 1990. WBV-1 also increased in frequency, reverting to its 1993 levels.

Table 5 Virulence combinations and their frequencies identified from year 2000 isolates compared with 1992-1999*

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

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

Table 6 Virulence frequencies corresponding to differential cvs for years 1992-2000

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

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

European leaf rust workers have, based on the responses of the core set of 15 Thatcher-Lr backcross lines to brown rust, adopted the octal/binary nomenclature system (Gilmour, 1973) to designate race numbers to pathotypes. A five digit number therefore describes the virulences carried. Races and their frequencies, identified from year 2000 isolates, are given in Table 7.

Table 7 Races and their frequencies, based on the reactions of Thatcher-Lr backcross lines, identified from the 2000 isolates of *Puccinia recondita*

Race (octal)	Frequency
0	0.13
10	0.04
20000	0.18
20020	0.04
20100	0.36
20120	0.09
20130	0.04
20220	0.04
20520	0.04
20720	0.04

Three isolates failed to infect any of the lines at either 10°C or 25°C. Race octal 20100 was predominant carrying virulence to Lr3 and Lr26, the resistances carried by the differential cvs Sterna (WBR-7) and Clement (WBR-1), respectively. The most widely virulent race, 20720, infected Lr3, Lr11, Lr15, Lr17 and Lr26. Virulence to all these individual genes has been identified previously in the UK pathogen population, although virulence to Lr3, Lr15 and Lr17 has always occurred at low frequency. Table 8 gives the virulence frequencies in year 2000 isolates corresponding to each Thatcher-Lr backcross line. Lines were classified as susceptible only if they expressed that reaction at both the low and high incubation temperatures. Virulence to Lr3 was at a higher frequency (29%) than in previous years; the most widely grown spring wheat Chablis carries this resistance.

Table 8 Virulence frequencies in year 2000 leaf rust isolates corresponding to each Thatcher-Lr backcross line

Thatcher line (Lr gene)	Frequency	Thatcher line (Lr gene)	Frequency
1	0	17	0.08
2a	0	19	0
2b	0	21	0
2c	0.04	23	0
3	0.29	24	0
9	0	26	0.83
11	0.61	28	0
15	0.08		

Isolates carrying virulence to Lr2c declined in frequency from 52% in 1998 to 26% in 1999. In year 2000, only one isolate (4%) infected the line Lr2c in which resistance is more effective at high temperature. Other lines were susceptible to one or more isolates at 10°C, but resistant to some or all of them at 25°C; these were Lr1, Lr2a, Lr2b, Lr3, Lr9, Lr11, Lr15, Lr17, Lr21 and Lr23. Resistance conferred by Lr19, Lr24 and Lr28 was effective at both test temperatures. Virulence to Lr28 has been identified previously, but only at very low frequency.

Of the newly introduced wheat cvs, Access, Macro, Tanker, Biscay and Phlebas were resistant at 10°C and 25°C. Cultivars Solstice, Option, Deben and CPBT W64 were susceptible at 10°C but resistant to the majority of isolates at 25°C. One isolate, WBRS-00-12, infected all cvs at both temperatures. This isolate was the only one to overcome the resistances of cvs Storm and Ashby under the high temperature regime although neither of them was infected at 10°C by any isolate. Cultivar Oxbow was resistant, but expressed a mixed reaction to two isolates. The remaining cvs, namely Chatsworth, Morph and Wallace displayed mixed reactions to all isolates, with individual plants of a cv. sometimes expressing different infection types to an individual isolate. This complicated classification of the host:pathogen responses. However, it was notable that these three cvs were generally more susceptible under the low temperature regime.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Winter and spring wheat cvs, including those on the NIAB Recommended List, the standard differential cultivars and cv. Thatcher backcross lines carrying different Lr resistance factors, were sown in each of three nurseries. The nurseries were inoculated with one each of the following isolates of leaf rust:

WBRS-98-20 (*WBV-1,2,7)	ex cv. Chablis, Cambridge
WBRS-00-01 (*WBV-0)	ex cv. Claire, Cambridge
WBRS-99-10 (*WBV-1,2)	ex cv. Rialto, Cambridge

*Virulence factors identified in seedling tests.

Cultivar:isolate interactions were assessed by percentage 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).

Results

Good levels of infection were established on the susceptible check cultivar Arina (Table 9). Table 9 shows, the WBR resistance factors (where identified), the Lr genes, and the resistance type (seedling or adult) of the cultivars tested. With the exception of the standard differential cultivars, 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 & Park *et al.*, 2000).

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

Cultivars susceptible to the three isolates were generally less heavily infected by isolate WBRS-00-01 which, in seedling tests, failed to infect any of the standard differential cultivars. Cultivar Fundin (WBR-2) was, however, susceptible within the nursery into which this pathotype was introduced, suggesting contamination with naturally occurring pathotypes. Cultivar Sterna (WBR-7) was infected by isolate WBRS-99-10, not identified as carrying WBV-7 in seedling tests, suggesting contamination of this nursery also.

Some cultivars showed only low levels of infection with all isolates. These included cv. Shamrock (also infected at low levels in 1999 field nurseries at IGER). Interestingly, this cultivar has a NIAB disease rating of 4 and showed high levels of infection in NIAB spreader bed tests in 1999 (Clarkson and Mann, 2000). The explanation for these differences is unclear.

The majority of cultivars expressed high levels of resistance. Cultivars Hereward and Charger which showed good resistance this year, have been susceptible to different isolates of leaf rust in previous years' tests at IGER and also in spreader beds at NIAB, Cambridge. These cultivars are postulated as carrying the combined genes Lr 10 and 13. Virulence to Lr10 appears to be common in Europe. Resistance conferred by Lr13, which is of the adult plant type, also appears to be generally ineffective on its own, but continues to offer protection in combination with other genes (Winzeler, Mésterhazy, Park *et al.*, 2000). Of other cultivars showing resistance some are postulated to carry Lr37 (adult plant resistance). The resistance of cultivars designated as carrying this gene, on its own or in combination with other Lr genes, remains effective, although cvs Brigadier and Cockpit showed some infection, of a mixed type, in these field tests. Of the remaining cultivars that showed good resistance at IGER (Table 9), Deben, Tanker, Morph, Wallace and Imp became infected in year 2000 spreader bed tests at the NIAB, Cambridge (J. Clarkson, NIAB, pers. comm.). Cultivar Imp previously showed high levels of infection in IGER field tests. The winter wheat Claire was resistant to isolate WBRS-00-01 despite the fact that the leaf sample from which this isolate was cultured was originally collected from cv. Claire.

The reactions of the Thatcher near isogenic lines (NILs) are given in Table 10. Genes Lr9, Lr19, Lr24, Lr28 and Lr37 were highly resistant, as they are generally across Europe. Resistance conferred by lines carrying Lr20, Lr21 and Lr23 was also effective in current tests although these lines were heavily infected by isolate WBRS-98-20 in similar tests in 1999. Nevertheless, in 1999, Lr21 and Lr23 expressed an intermediate reaction type.

Several of the NILs were susceptible in field tests although they were classified as resistant to one or more isolates in seedling tests . This was probably due to the effect of temperature on the host:pathogen interactions as lines were only classified as susceptible in seedling tests if they expressed that reaction at 10°C and 25°C. Alternatively, it may be that field nurseries were contaminated with naturally-occurring pathotypes.

CONTROLLED ENVIRONMENT TESTS

Winter and spring wheat cultivars, currently on the NIAB 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. These tests also included cv. Thatcher backcross lines carrying different Lr resistance factors which have been generally effective against the UK pathogen population, and the spring wheat standard differential cvs Sappo and Halberd which carry resistance factor 3 and 4 respectively. Two replicates of each cultivar were inoculated with one each of the following isolates:

WBRS-00-18	(WBV-1,2,7)	cv. Claire, Lincs
WBRS-00-14	(WBV-1,2,7)	cv. Tanker, Cambs
WBRS-00-25	(WBV-1,7)	cv. Wallace, N. Yorks

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).

Results

Table 11 shows percentage of flag leaf area infected and reaction type classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4).

All the cultivars from the current (2001) NIAB Recommended List of spring and winter wheats were resistant, although cvs Wallace, Morph and Paragon were susceptible at the higher temperature regime. Some other cvs were more heavily infected at 25°C but gave a mainly resistant reaction type.

Cultivar Claire was resistant to isolate WBRS-00-18 even though the isolate originated from an infected crop of cv. Claire showing an overall disease level of 10%. Similarly, cv. Wallace gave a resistant reaction type at 10°C to isolate WBRS-00-25, even though the isolate originated from a crop of Wallace that had shown low levels of brown rust infection. At 25°C, however, cv. Wallace gave a susceptible or mixed reaction type and high leaf area infected.

Of the Thatcher backcross lines, Lr17 was susceptible to isolate WBRS-00-18 but, at the lower test temperature, gave a resistant reaction type to the other isolates. Genes Lr21 and Lr23 showed high percentages of leaf area infection but resistant or intermediate reaction types to all isolates at both temperatures. All other NILs, with the exception of Lr37, were resistant to all isolates at both temperatures.

In these tests the near isogenic line Lr37 was susceptible at 25°C but expressed a mainly resistant reaction at 10°C, although two of the isolates gave high percentage leaf area infection. Adult plant resistance conferred by gene Lr37 appears to be effective, under field conditions, across Europe (Winzeler, Mésterhazy, Park *et al.*, 2000). In some cvs Lr37 is thought to be the sole resistance gene present (Cockpit, Malacca) but it is postulated that the gene is combined with other Lr genes in several current UK wheat cultivars. All cultivars carrying Lr37 and the Thatcher backcross line Lr37, have proved resistant in field nurseries at IGER and in controlled environmental tests in 2000.

ACKNOWLEDGEMENT

I am grateful to Dr Tim Carver (IGER) for his comments on this report.

REFERENCES

Gilmour, J. (1973). Octal notation for designating physiologic races of plant pathogens. *Nature* Lond. 242-260.

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

Bayles, R.A. and Stigwood, P.L. (1999). Yellow rust of wheat. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp.27-52.

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

Table 9 †Percentage infection of spring and winter wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 2000

Isolate/Cultivar	[NIAB rating]	WBR-	Postulated Lr genes	Resistance type	WBRS-98-20 (WBV-1,2,7)	WBRS-00-01 (WBV-0)	WBRS-99-10 (WBV-1,2)
Clement		1	26	OR	26	4	23
Rialto	[4]	1+	10,13,26	Seed+APR	9	5	13
Isengrain			14a		26	5	30
Fundin		2	17b	OR*	20	14	24
Norman		2+		OR*	13	10	14
Hobbit		2+		OR*	13	5	13
Huntsman		5	13	APR	30	22	23
Buster			13	APR*	25	12	28
Arina		(suscept.check)	13?		43	41	45
Gamin		6		APR	12	5	10
Avalon		9		APR*	7	7	5
Sterna		7	3	OR*	16	1	9
Chablis	[5]	7	3	OR*	1	1 MS	0.1
Shiraz	[9]	7+	3+	Seed+APR*	0	0	0
Odyssey					10	1	12
Option	[7]			*	8	1	7
Canterbury					5	1	5
Shamrock	[4]			APR	5	1	3
Cockpit			(37)	APR	3 MS	0.4	3 MS
Brigadier			13+26+37	Seed+APR	3 MS	0.1	13 MR
Hereward	[8]		10+13	Seed+APR*	0	0.2	0
Charger	[6]		10+13	Seed+APR*	0.2	0.1	0
Reaper			(37)	Seed+APR*	0	Trace	0
Consort	[5]			APR	Trace	2	Trace
Savannah	[9]		(26+37)	OR	0.2 MS	0.1 MS	0.2 MS
Buchan	[9]		(26+37)	OR*	0	0	0
Malacca	[8]		(37+)	APR	0	0.3 MS	0
Genghis			(10+26+37)	OR*	0	0	0
Madrigal	[9]		(10+26+37)	OR	0	0	0
Equinox	[9]		(10+26+37)	OR	0	0	0
Napier	[9]		(10+26+37)	OR*	0	0	0
Aardvark			(10+26+37)	OR	0	0	0
Eclipse			(10+37)		0	0	0
Deben	[7]			OR*	0.1	Trace	0.2
Imp	[5]			APR*	1	0.1	1
Tanker	[8]		(26+)	OR	0	0	Trace
Ranger				APR	0	0	0
Claire	[9]			APR	0	0	0
Oxbow			(26+)	OR	0	0	0
Potent					0	0	0
Biscay	[9]		(26+37)	OR	0	0	0
Morph	[9]			*	0	0	0
Wallace	[8]			*	0	0	0
Ashby	[8]			OR	0	0	0
Paragon	[9]			APR*	0	0	0
Sappo		3	20	OR*	1	Trace	Trace
Halberd		4	20	OR*	Trace	Trace	0

†Mean of 3 replicates, 2 assessment dates. All reaction types susceptible unless stated.
MS = mixed susceptible; >1 reaction type is expressed by a single cv., classification is based on the prevalent response.
APR = adult plant resistance; OR = overall resistance. * temperature sensitive resistance.
( ) postulated Lr genes based on links to resistances for stripe rust.
[ ] NIAB 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 2000

Isolate Lr gene	Resistance type	WBRS-98-20 ▪(WBV-1,2,7) (Lr-3,11,14a,15,17,26)	WBRS-00-01 ▪(WBV-0)	WBRS-99-10 ▪(WBV-1,2) (Lr-2b,2c,11,14a,26)
1	OR*	14 MS	14	6
2a	OR*	28	27	12
2b	OR*	31	28	18
2c	OR*	44	45	39
3	OR*	46	6	38
9	OR*	0	1 R	0
11	OR*	38	34	28
13	APR*	24	29	23
14a	OR*	45	12	45
15	OR*	41	9	41
17	OR*/APR	30 MR	14 MR	22 MR
19	OR	-	0	0
20	OR*	0.3	0	0.3
21	OR	0.3 Int.	3 MR	Trace
23	OR*	4 Int.	6 Int.	2 Int.
24	OR	0	0	0
26	OR	41	10 MS	35
28	OR*	Trace R	Trace R	Trace R
37	APR	7 MR	2 MR	7 MR

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

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

Isolate		WBRS-00-18 ▪(WBV-1,2,7)		WBRS-00-14 ▪(WBV-1,2,7)		WBRS-00-25 ▪(WBV-1,7)	
		Incubation Temperature °C					
Cultivar [NIAB rating]	Resistance type	10	25	10	25	10	25
Buchan [9]	OR*	0	0	0	0	0	0
Madrigal [9]	OR	0	0	0	0	0	0
Oxbow	OR	0	8 R	0	0	0	0
Biscay [9]	OR	0	5 R	0	15 R	0	0
Equinox [9]	OR	0	3 R	0	0	0	0
Claire [9]	APR	0	0	0	8 R	0	20 R
Tanker [8]	OR	0	5 R	5 R	10 MR	0	8 R
Patent		0	10 R	6 R	5 R	5 R	8 R
Ashby [8]	OR	0	20 MR	0	20 MR	0	20 MR
Malacca [8]	APR	0	20 MR	0	18 MR	0	13 MR
Shiraz [9]	Seedling+APR*	0	20 S	0	20 S	0	10 S
Wallace [8]	*	10 R	25 MS	5 R	25 S	20 R	20 S
Morph [9]	*	20 R	15 S	20 R	15 S	10 R	15 S
Paragon [9]	APR*	20 R	40 S	15 R	35 S	0	40 MS
Halberd (WBR-4)	OR*	25 MR	15 S	5 R	20 S	25 MR	25 MS
Sappo (WBR-3)	OR*	10 MS	35 S	0	15 S	25 R	30 S
Lr 9	OR	5 R	0	5 R	0	0	0
LR 17	Seedling+APR*	15 S	30 MS	35 R	25 MS	10 MR	5 MR
LR 19	OR	0	0	0	0	0	0
LR 21	OR	35 MR	35 Int.	15 R	25 Int.	10 R	10 Int.
LR 23	OR*	35 Int.	35 R	35 Int.	30 R	15 Int.	5 R
LR 24	OR	0	0	0	0	0	0
LR 28	OR*	3 R	0	0	0	3 R	0
LR 37	APR*	35 MR	25 MS	35 MR	35 MS	10 MR	15 MS

†Reaction type 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 cv., classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant; Int. = intermediate
Mean of 2 plants
APR = adult plant resistance; OR = overall resistance
* = temperature sensitive resistance against some pathotypes
▪Virulence factors identified in seedling tests
[ ] NIAB rating: 1 = susceptible; 9 = resistant

BROWN RUST OF WHEAT: NIAB ADULT PLANT TESTS

J D S CLARKSON and S J MANN

NIAB, Huntingdon Road, Cambridge CB3 0LE

INTRODUCTION & METHODS

Four outdoor beds each of winter and spring wheat cultivars were inoculated with individual isolates of brown rust (*Puccinia triticina* Erikss.), as part of the Recommended List testing programme funded by HGCA. One further bed each of winter and spring wheat cultivars was inoculated with a mixture of the four individual isolates for testing of resistance/susceptibility of NL1 cultivars to brown rust.

Methods employed were similar to those of previous years. Isolates were selected as being representative of the current brown rust population as given by Jones (1999) and are shown in Table 1. The results, expressed as the mean percentage leaf area infected at the GS75 (3 July 2000) assessment, are given in Table 2.

Table 1 Brown rust isolates used in outdoor tests, NIAB Cambridge, 2000

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

Infection was established satisfactorily in 2000, facilitated by the favourable weather conditions for brown rust infection and development during the summer. Most current Recommended List winter wheat cultivars are resistant or moderately resistant to brown rust, including the newly Recommended cultivars Biscay, Tanker, Deben and Option (Table 2). However, a number of important cultivars – *eg* Consort, Shamrock, Riband and Soissons – are susceptible. Isolate WBRS-98-20 produced low levels of infection on the resistant (rating 9) cultivars Genghis, Madrigal and Reaper. Reaper was also infected by isolate WBRS-99-10: Jones (2000) also found some infection on this, and other resistant cultivars, in 1999 controlled environment tests. Isolate WBRS-99-8 gave slight infection on Savannah (rating 9). Hereward, Malacca and Tanker (all rating 8) were infected to varying degrees by all four isolates.

The current 2001 Recommended List spring wheat cultivars Chablis, Paragon, Shiraz, and newcomers Ashby, Morph and Wallace, are all resistant or moderately resistant to brown rust, while Imp is susceptible (rating 5). Isolates WBRS-98-20 and WBRS-99-10 produced considerable infection on Chablis (rating 6) and a lower level of infection on Morph (rating 8).

ACKNOWLEDGEMENT

We 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.

Table 2 Mean % leaf area of winter & spring wheat cultivars infected by brown rust in field tests, 2000

	VARIETY	ISOLATE... NIAB RATING*	WBRS-98-20 (V1,2,6,7)	WBRS-99-10 (V1,2,6)	WBRS-99-11 (V2,6)	WBRS-99-8 (V6)	ISOLATE MIXTURE#
WW	AARDVARK	9	0	0	0	0	x
	BISCAY	**9**	0	0	0	0	x
	BUCHAN	**9**	0	0	0	0	x
	CLAIRE	**9**	0	0	0.3	0	x
	COCKPIT	9	1.5	1.0	0.3	0.3	x
	ECLIPSE	9	0.5	0.8	0.8	0.5	x
	EQUINOX	**9**	0	0	0	0	x
	GENGHIS	9	4.3	1.8	0	0	x
	MADRIGAL	**9**	4.2	0	0.2	0	x
	NAPIER	**9**	0.0	0	0	0	x
	OXBOW	9	0.0	0	0	0	x
	REAPER	9	2.8	4.3	0.8	0.2	x
	SAVANNAH	**9**	0.2	0	0.8	3.0	x
	HEREWARD	**8**	10.8	17.7	13.3	14.0	x
	MALACCA	**8**	11.7	7.5	10.0	5.8	x
	TANKER	**8**	19.7	5.3	8.7	17.7	x
	DEBEN	**7**	9.2	16.3	7.3	23.2	x
	OPTION	**7**	15.8	22.0	17.2	27.3	x
	CHARGER	**6**	15.4	12.5	26.8	22.0	x
	CONSORT	**5**	23.7	30.8	25.0	30.0	x
	RIALTO	**4**	38.3	41.7	29.8	24.5	35.0
	SHAMROCK	**4**	25.3	31.2	30.5	31.2	x
	RIBAND	**3**	45.8	42.5	38.8	40.5	39.7
	BUSTER	2	45.0	41.7	45.0	43.7	x
	SOISSONS	**2**	50.8	48.5	35.3	35.3	45.2
	AVALON		24.8	27.8	30.3	36.8	x
	HAVEN		21.3	34.8	20.0	23.7	x
	M HUNTSMAN		43.3	40.2	32.7	43.0	x
	MERCIA		29.7	35.2	43.0	37.2	x
	PASTICHE		39.3	36.7	22.0	29.5	x
	SLEJPNER		38.3	37.5	20.3	34.0	x
	VIRTUE		28.7	16.2	32.8	35.7	x
SW	**PARAGON**	9	0.8	0	0	0	x
	SHIRAZ	9	0	0	0	0	x
	ASHBY	**8**	0.2	1.2	2.5	5.8	x
	MORPH	**8**	18.5	11.7	4.2	4.5	x
	WALLACE	**8**	0.2	3.7	6.7	6.7	x
	CHABLIS	6	39.0	24.7	10.2	15.0	29.7
	IMP	5	50.3	12.5	12.0	13.8	13.5
	ALEXANDRIA		51.2	33.8	27.0	38.3	35.8

x Not tested in 2000.

* 1-9 scale (1 = susceptible; 9 = resistant); NIAB Recommended List **2001** varieties in **bold** type.

\# Mixture of isolates WBRS-98-20, WBRS-99-10, WBRS-99-11, WBRS-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), VLa, Va12* and *Va7* were present at high levels in all populations. The number of isolates carrying *Vh* continued to decline. *Va3* was detected more frequently than in previous years. Barley mildew isolates continued to become more complex, the majority carrying eight or more virulence factors. Although nearly 200 pathotypes were detected in 2000, the number of pathotypes identified continued to decline. The dominant pathotype, *Vh,Vra,Vg,V(CP),VLa,Va12,Vk1,Va7,V(Ab),Va1*, although present in only 10% of the isolates tested, has become more frequent over the last few years. Of the winter cultivars, only Vanessa and Leonie have effective specific resistance, although many have good non-specific resistance. *Mlo* remains the only effective resistance in spring cultivars. In tests, isolates from 1998 and 1999 continued to give low levels of infection on *mlo* cultivars. No reduced sensitivity to strobilurins was detected.

INTRODUCTION

Infections of mildew on barley were more severe and prolonged in 2000 than for several years. Another mild winter and cool spring resulted in early infection which continued to spread throughout the spring and early summer. Unlike the previous two years the development of disease was not curtailed by heavy spring rain. The majority of sampling was carried out in April, May and early June, when excellent samples were collected.

METHODS

Virulence survey

204 samples were collected from infected leaves in 2000, the majority from NIAB Recommended List trial plots. 30 samples failed to produce viable conidia but single colony isolates were cultured from the remaining 174 samples. The 330 isolates tested were collected from the following 8 locations:

Morley, Norfolk	82	isolates	Harper Adams, Shropshire	32	isolates
Headley Hall, N. Yorks.	66		Cockle Park, Northumberland	24	
Ashford, Kent	55		Bridgets, Hants.	19	
NIAB HQ, Cambridge	50		Walberswick, Suffolk	2	
			Total	**330**	

Isolates were collected from the following 14 spring and 32 winter cultivars:

Spring cultivars

	isolates		isolates		isolates
Optic	12	Prisma	4	Cellar	2
Tavern	9	Neruda	4	Brise	2
Riviera	9	Static	2	Berwick	2
Delibes	6	Chariot	2	Chalice	1
County	5	Century	2		

Winter cultivars

	isolates		isolates		isolates
Antonia	14	Leonie	10	Vertige	8
Avenue	14	Opal	10	Flute	7
Sumo	14	Pearl	10	Muscat	7
Artist	13	Siberia	10	Manitou	6
Jewel	12	Pastoral	9	A92-39	2
Regina	12	Vanessa	9	A92-404	2
Intro	11	Angela	8	Carat	2
Haka	10	Fanfare	8	Milena	2
Hanna	10	Gleam	8	Scylla	2
Heligan	10	Halcyon	8	VDH2161-95	2
Jackpot	10	Melanie	8		

Single colony isolates were also taken from plants of the susceptible spring cultivar Golden Promise exposed to the local air spora in January, March, June and October. Isolates were tested for virulence on detached leaves of the differential cultivars listed in Table 1.

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

Cultivar	Resistance genes	BMR group
Golden Promise	none	0
Weihenstephan 37/136	*Mlh*	1a
Weihenstephan 41/145	*Mlra*	1b
Goldfoil	*Mlg*	2a
Zephyr	*Mlg, Ml(CP)*	2a, 2b
Midas	*Mla6*	3
Lofa Abed	*MlLa*	4
Hassan	*Mla12*	5
Hordeum 1063	*Mlk1*	6a
Porter	*Mla7*	6b
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, Sumo, Leonie, and Carola and the spring cultivar County, which have unknown resistance, were also included in some tests.

Virulence for mlo cultivars

Further tests were carried out with the isolates selected from the 1998 population which had been used in previous tests, together with isolates from 1999 which had given increased levels of infection in the original differential tests. Isolates were inoculated onto detached leaves of five cultivars which are thought to carry *mlo* resistance and assessed for leaf area infected.

Fungicide sensitivity tests

168 bulk isolates were tested for sensitivity to strobilurin fungicides by inoculating detached leaves from plants treated with half rate azoxystrobin.

RESULTS AND DISCUSSION

Virulence

The results of the 2000 survey are shown in Table 2. Virulence for *Mlra, Mlg, Ml(CP), MlLa, Mla12, Mla7, Ml(Ab)* and *Mla1* was high in all the populations screened. There continued to be selection for *Vra, Vg, V(CP)* and *Va7* by winter cultivars carrying the corresponding resistance and by both winter and spring cultivars possessing *Mla12*. Only spring cultivars are known to carry *Ml(Ab)*. The area of cultivars possessing *MlLa* and *Mla1* is small despite the high frequency of the corresponding virulence.

Virulence for *Mlh* was higher in the March collection of airborne spores and lowest in October. Only winter cultivars carry *Mlh* and therefore select for *Vh*, with the greatest effect of this selection apparent in late winter. Autumn infections of powdery mildew are derived from populations that have multiplied on spring cultivars during the early summer. It appears, therefore, that *Vh* declines in populations in the absence of host selection. *Vh* occurred less frequently in populations derived from cultivars lacking *Mlh*, as seen by the difference between the data for all leaf isolates and the non-corresponding virulence frequency.

There was little selection for *Va6, Va9* and *Va13* in 2000, but nevertheless these virulences were detected in all the populations tested. Virulence for *Mlk1* was common despite the absence of selection.

Although no cultivars with *Mla3* have been grown in the UK, low levels of *Va3* have been detected in most years. However, virulence for *Mla3* occurred at an unexpectedly high level in the October 2000 sample of airborne spores. Although 13 of the 19 isolates with *Va3* possessed the same virulence combination and therefore may be the product of a single clone, five pathotypes in all were detected.

Table 2 Virulence frequencies in single colony isolates of barley mildew from infected leaves (leaf sample) and from random samples of airborne spores, and the area of barley cultivars with the corresponding resistance factors in 2000.

Virulence gene	% Frequency of virulence factors						% Area of corresponding resistance #
	Leaf sample		Random samples of airborne spores				
	All data	Non-corresponding virulence *	January	March	June	October	
Vh	58	42	41	51	43	31	20
Vra	100	100	100	100	100	98	26
Vg	97	96	98	96	93	99	18
V(CP)	96	96	95	95	93	99	18
Va6	28	24	26	24	11	8	<1
VLa	87	87	90	89	79	93	<1
Va12	91	89	83	91	91	75	24
Vk1	64	64	63	61	44	69	0
Va7	94	94	96	96	88	100	19
V(Ab)	82	81	74	77	88	66	22
Va1	73	72	56	52	53	73	2
Va9	25	23	26	33	31	45	0
vo	0	0	0	0	0	0	17
Va13	8	8	13	12	15	18	<1
Va3	3	3	2	4	1	24	0
No. of isols.	330		99	100	80	80	

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

NIAB (2000)

Table 3 compares the virulence frequencies for 1992 to 2000. The frequency of virulence for *Mlra* has remained at 100% for several years while *Vg* and *V(CP)* have increased slightly over the last five years to almost the maximum level detected in 1992. The increase in the frequency of *Va12* and *Va7* over the last two years matches the increase in the area of cultivars carrying *Mla12* (Jewel and Flute) and *Mla7* (Regina) respectively. For many years *Vh* remained near 100% despite fluctuations in the area of cultivars carrying the corresponding resistance and was considered fixed in the population. However, since 1996 *Vh* has declined steadily suggesting that pathotypes with *Vh* are at a disadvantage in the absence of the selective host.

The reduction in the incidence of *Va6* and *Va13* in the last few years corresponds with the decrease in area of cultivars with *Mla6* and *Mla13*. The area of cultivars carrying *MlLa* and *Mla1* has also declined but this has not been mirrored by decreasing frequency of *VLa* and *Va1*, both of which have become more frequent in the mildew populations of the last decade. Little change has been observed in the frequency of *Vk1* and *Va9*, for which there is now no selection. The level of *V(Ab)*, like the area of *Ml(Ab)*, has fluctuated throughout the 1990s.

Table 3 Virulence frequencies in barley mildew, 1992 to 2000.

Virulence gene	Virulence frequency (%) *								
	1992	1993	1994	1995	1996	1997	1998	1999	2000
Vh	78	78	79	70	78	68	61	58	50
Vra	100	100	99	100	100	100	100	100	100
Vg	99	96	95	95	96	95	97	97	97
V(CP)	98	92	88	90	90	93	94	95	96
Va6	31	35	31	34	30	25	31	26	23
VLa	24	22	25	31	56	58	72	89	88
Va12	73	72	67	71	70	73	76	87	88
Vk1	77	75	72	72	76	71	73	66	61
Va7	78	76	69	73	76	73	76	85	95
V(Ab)	72	76	74	67	62	52	53	71	79
Va1	13	18	23	27	38	36	45	64	65
Va9	26	29	34	33	37	33	32	25	29
Va13	42	38	43	37	41	39	25	19	11
Va3	-	1	<1	<1	<1	1	1	1	5
Number of isolates	462	628	539	552	428	551	743	629	689

* Mean of leaf samples and random samples of airborne spores for each year. Data from Slater & Clarkson (2000).

Complexity of isolates

The barley mildew population continues to become more complex with over 80% of isolates carrying eight or more virulence factors. Table 4 compares the number of virulence factors carried by isolates tested in 1992 - 2000. In 1992, only 10% of the population possessed 10 or more virulence factors compared to over 30% in 2000.

Table 4 Comparison of the complexity of isolates collected from 1992 to 2000.

Number of virulence factors	% Frequency of isolates with each number of virulences*								
	1992	1993	1994	1995	1996	1997	1998	1999	2000
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	<1	0	<1	<1	0	0	0	0
3	<1	<1	0	<1	1	0	<1	0	0
4	<1	4	1	1	1	1	1	1	1
5	2	18	4	4	3	4	4	1	1
6	8	34	10	11	7	11	10	8	6
7	20	27	24	19	14	17	15	10	8
8	35	10	25	28	22	23	22	21	21
9	25	4	16	20	24	21	18	18	26
10	7	1	12	10	16	16	20	25	24
11	3	<1	4	5	10	4	6	12	11
12	<1	0	2	1	8	2	2	3	1
13	0	0	0	0	3	<1	<1	1	0
Total number of isolates	462	628	539	552	428	551	743	629	689

* includes all virulences listed in Table 2

Fewer pathotypes were again identified in 2000 (see Table 5). The most commonly identified pathotypes were:-

Vh,Vra,Vg,V(CP),VLa,Va12,Vk1,Va7,V(Ab),Va1 (10% of the isolates tested)
Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1 (6% of isolates)
Vh,Vra,Vg,V(CP),Va6,VLa,Va12,Vk1,Va7,V(Ab),Va1 (5% of isolates).

Table 5 Number of pathotypes identified, 1995-2000.

	Total number of isolates tested	Number of pathotypes	Frequency of the commonest pathotype(%)
1995	552	298	3
1996	428	238	3
1997	551	277	4
1998	743	302	6
1999	629	202	8
2000	689	190	10

Of the 190 pathotypes identified, 117 were represented by only a single isolate. The decrease in the number of pathotypes detected, as shown in Table 5, suggests that some pathotypes, including the dominant one, are becoming more frequent. This could represent the early stages of a situation similar to that in the wheat mildew population (Clarkson and Slater 2000), where a very few pathotypes dominate the population. As there are few novel types of resistance appearing in new cultivars there is continuing selection for the same virulence factors. The dominant pathotype is capable of infecting the majority of winter barley cultivars and all the non-mlo spring cultivars.

Infection of barley cultivars

The barley cultivars in 2000 NIAB RL trials and the proportion of the population to which they are potentially susceptible are shown in Table 6. Over 50% of the winter barley grown is susceptible to over 80% of the population, while over 50% of the population is capable of infecting 25% of spring barley. However, many of these cultivars show good non-specific resistance as shown by their high NIAB rating, e.g. Flute is potentially susceptible to 88% of the population but has a NIAB rating of 8. This type of resistance is more likely to prove durable than a combination of specific resistance factors. Leonie, Carola and Vanessa all appear to possess specific resistance factors which, in the case of Leonie and Vanessa, are already matched by detectable levels of virulence. Whether these cultivars also possess non-specific resistance is not yet obvious: only when specific virulence reaches levels sufficient to cause significant field infections will the relative effect of specific and non-specific resistance become apparent. If Leonie and Vanessa become widely grown, it is likely that the corresponding specific virulence will increase in frequency. It is important, therefore, that these crops are constantly monitored so that any breakdown of resistance is identified as early as possible.

Table 6 Proportion of mildew isolates tested in 2000 able to infect barley cultivars in Recommended List trials (NIAB rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Avenue (7)	100	Melanie (6)	50
Halcyon (7)	100	Siberia (7)	50
Hanna (4)	100	Antonia (6)	47
Heligan (3)	100	Opal (7)	47
Intro (6)	100	Pearl (8)	47
Muscat (6)	100	Vertige (5)	47
Pastoral (3)	100	Artist (6)	44
Fanfare (5)	97	Manitou (5)	29
Regina (3)	95	Jackpot (7)	23
Sumo (6)	94	Gleam (6)	16
Flute (8)	88	Leonie (8)	9
Jewel (7)	88	Vanessa (8)	5
Angela (8)	50	Carola (8)	<1
Haka (7)	50		

Spring cultivars	Proportion (%)	Spring cultivars	Proportion (%)
Optic (7)	76	Chariot (9)	0
Prisma (4)	75	Chime (9)	0
Delibes (6)	55	Dandy (9)	0
Tavern (7)	55	Decanter (9)	0
County (8)	53	Neruda (9)	0
Annabell (9)	0	Otira (9)	0
Berwick (9)	0	Pewter (9)	0
Brise (9)	0	Prestige (9)	0
Cellar (9)	0	Riviera (9)	0
Century (9)	0	Saloon (9)	0
Chalice (9)	0	Static (9)	0

Virulence for *mlo* cultivars

The results of tests with isolates designated Apex + and Apex 0 from 1998 and 1999 are shown in Table 7. The isolates designated Apex +, from both 1998 and 1999, again gave more infection than the Apex 0 isolates.

Table 7 % Infection, relative to Golden Promise, on cultivars carrying *mlo* resistance by isolates collected in 1998 and 1999.

no of isols	Year collected	Original designation of isolates	GP	Chariot	Landlord	Riviera	Chalice	Apex
1	1970	Apex 0	100	0	0	0	0	0
3	1998	Apex 0	100	0	0.7	0	8.7	3.2
2	1999	Apex 0	100	0.1	0.7	0.7	15.3	4.6
7	1998	Apex +	100	2.8	2.4	7.2	9.9	7.7
12	1999	Apex +	100	2.8	1.2	5.5	7.2	9.5

Although infection levels observed on the *mlo* differentials in tests are low, an increasing number of isolates give some reaction on these cultivars. Table 8 shows the proportion of the isolates tested in 2000 that infected Apex and Riviera. For both cultivars, the number of infective isolates has increased. The number of isolates giving some infection on Riviera has been rising since 1997 but the number infecting Apex had remained constant. However, in 2000, there also appears to have been an increase in the number of isolates giving low levels of infection on Apex.

Table 8 Proportion of isolates infecting Apex and Riviera in differential tests, 1996-2000.

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

Resistance factors in new cultivars

The resistance factors carried by cultivars in NIAB RL trials in 2000 are shown in Table 9. Many of the commonly grown winter cultivars posses good non-specific resistance in addition to the resistance factors listed. Of the winter cultivars, only Vanessa, Leonie and Carola carry effective specific resistance, although a low level of virulence for Vanessa and Leonie was detected. Virulence for Carola has yet to be confirmed in the single isolate that gave some infection on that cultivar in the original differential test. Of the 51 isolates virulent on Leonie, 32 were also virulent on Vanessa; all Vanessa-virulent isolates also infected Leonie. It seems likely, therefore, that Vanessa and Leonie carry common resistance but Vanessa possesses additional resistance not found in Leonie. Although Sumo carries unknown specific resistanc, the corresponding virulence was present in over 90% of the isolates tested.

Table 9 Resistance genes of barley cultivars (2001 Recommended List cultivars in **bold**)

None	*Mla12*	*mlo*
Halcyon (W)	**Flute** (W)	Annabell (S)
Hanna (W)	**Jewel** (W)	Berwick (S)
		Brise (S)
Mlra	*Mlh,Mla12*	**Cellar** (S)
Avenue (W)	Artist (W)	Century (S)
Heligan (W)		**Chalice** (S)
Intro (W)	*Mla9*	**Chariot** (S)
Muscat (W)	**Manitou** (W)	**Chime** (S)
Pastoral (W)		**Dandy** (S)
	Mla7 (Mlra?)	**Decanter** (S)
Mlh,Mlra	**Regina** (W)	Neruda (S)
Angela (W)		Otira (S)
Haka (W)	*Mlh,Mlra,Mla7*	**Pewter** (S)
Melanie (W)	**Vertige** (W)	Prestige (S)
Siberia (W)		**Riviera** (S)
	Mla12,Ml(Ab)	**Saloon** (S)
Mlh, Mlg	**Optic** (S)	**Static** (S)
Antonia (W)		
	Mlg,Ml(CP),Mla12,Ml(Ab)	Unknown
Mlra,Mlg,Ml(CP)	**Prisma** (S)	Carola (W)
Fanfare (W)		**Leonie** (W)
Opal (W)	*Mla1(Ml(Ab),MlLa?),*	**Sumo** (W)
Pearl (W)	**County** (S)	**Vanessa** (W)
Mla6 (Mlra?)	*Ml(Ab),Mla1*	
Jackpot (W)	**Delibes** (S)	
	Tavern (S)	
Mlh,Mlra,Mlg,Ml(CP),Mla6		
Gleam (W)		

(W) winter cultivar, (S) spring cultivar

Fungicide sensitivity

Resistance to strobilurin fungicides in barley mildew was detected in Germany in 1999 and France in 2000 (Heaney et al, 2000) but tests in the UK in 1998 and 1999 failed to detect any reduction in sensitivity (Napier et al, 2000). None of the 168 bulk isolates tested on azoxystrobin-treated leaves exhibited reduced sensitivity when compared to control isolates collected prior to the introduction of strobilurins. Resistant wheat mildew isolates were first detected in Germany in 1998 and subsequently reduced sensitivity was identified in 1999 throughout Europe and the UK. It appears possible, therefore, that resistance to strobilurins will develop in the UK barley mildew population. Only constant monitoring of the population will detect resistance in the early stages and assist the development of strategies to safeguard effective fungicide use.

REFERENCES

Clarkson, J.D.S. and Slater, S.E. (2000). Mildew of wheat. *UK Cereal Pathogen Virulence Survey 1999 Annual Report*, pp 22-28.

Heaney, S.P., Hall, A.A, Davies, S.A. and Olaya, G. (2000). Resistance to fungicides in the Qo1-STAR cross-resistance group; current perspectives. *Proceedings of the Brighton Crop Protection Conference - Pests and Diseases 2*, 755-762.

Napier, B.A.S., Bayles, R.A. and Stigwood, P.L. (2000). Sensitivity of powdery mildew and yellow rust to DMI, morpholine and strobilurin fungicides in England and Scotland. *Proceedings of the Brighton Crop Protection Conference - Pests and Diseases 1*, 427-434

NIAB (2000). Seed Production No. 22 (November 2000).

Slater, S.E. and Clarkson, J.D.S. (2000). Mildew of barley. *UK Cereal Pathogen Virulence Survey 1999 Annual Report*, pp 48-56.

MILDEW OF BARLEY IN NORTHERN IRELAND

P C MERCER and A RUDDOCK

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

Thirty isolates were tested, 22, from winter and 8 from spring barley. Results were generally reasonably consistent with previous seasons, but there was a slight rise in isolates which produced a virulent score on *cv.* Apex and more so on *cv.* Atem. There was, however, no general field break-down in a generally very low mildew year. *Va3* showed an unexpected increase.

INTRODUCTION

Because of an almost complete lack of mildew in 1999, particularly at the usual time of isolation (last week in June) no results were recorded in that year. In 2000, there was again very little disease, but attempts were made to obtain isolates a month earlier than previously and this resulted in the isolation and testing of 30 isolates, 22 from winter and 8 from spring barley cultivars. 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 virulence of isolates and their genetic designations is shown in Table 2.

The most commonly sown cultivars in the season 1999/00 are shown in Table 1. This Table has become more stable in recent seasons (Mercer, 1999, 2000), for both winter and spring barley, but practically all spring barley cultivars now carry *mlo*.

Table 1 Percentage use of barley cultivars in N. Ireland (1999/00)

Spring cultivars *(resistance genes)*	**%**	**Winter cultivars** *(resistance genes)*	**%**
Riviera (*mlo*)	61	Regina (*Mlra, Mla12*)	46
Dandy (*mlo*)	22	Jewel (*Mla12*)	31
Century (*mlo*)	8	Pastoral (*Mlra*)	14
Static(*mlo*)	3	Heligan (*Mlra*)	4
Ferment (*?*)	3	Vertige (*Mlh, Mlra, Mla7*)	3
Felicie (*Mlg, Ml(CP), Mla9*)	2		

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 consistent with previous years. *Va7*, *Va1*, *Va9*, *Va13*, *VLa+Vk*, *Vk+Va7*, *Va7+V(Ab)* and have returned to values similar to 1997, after low values in 1998. This is also true of the combined virulence *VLa+Va13* which had a particularly low value in 1998. There was a considerably higher level of *Va3* which mirrored a large rise in this virulence in Britain (Slater and Clarkson, this report), although there are no cultivars grown widely in the UK, either presently or in the recent past, which carry the resistance group. There was a slightly higher level of mildew on Apex (*mlo*) and a surprisingly high level on Atem (*mlo+MlLa*). However, although almost the entire spring barley area in N. Ireland is now sown to *mlo* cultivars (Table 1), with resulting high pressure on the gene, there is little evidence of field break-down.

Table 3 Frequencies of virulence alleles from isolates collected from barley crops from 1990 to 2000

Virulence Gene(s)	BMV group	Frequency of virulence alleles									
		1990	1991	1992	1993	1994	1995	1996	1997	1998	2000#
Vh	1a	na	na	na	na	na	na	na	75	60	55
Vra	1b	na	na	na	na	na	na	na	83	77	65
Vg, V(CP)	2	43	64	39	43	77	50	52	67	60	86
Va6	3	41	54	36	47	56	26	41	58	41	52
VLa	4	27	57	25	47	42	44	33	75	79	87
Va12	5	46	54	31	67	74	61	80	58	52	52
Vk1	6a	na	na	na	na	na	na	na	83	75	87
Va7	6b	na	na	na	na	na	na	na	75	41	87
V(Ab)	6c	na	na	na	na	na	na	na	100*	73	75
Va1	7	20	14	14	40	22	41	7	100*	39	80
Va9	8	27	30	28	30	29	46	45	67	42	65
corresponding to *mlo*	9	na	na	na	na	na	na	na	8	9	12
Va13	10	14	46	25	27	37	19	38	50	29	50
Va3	11	na	na	na	na	na	na	na	17	5	50
Va6, VLa	3 + 4	67	39	36	30	50	22	33	67	41	41
VLa, Va12	4 + 5	27	50	47	30	53	24	33	67	31	71
VLa, Vk	4 + 6a	50	50	44	30	24	33	48	67	52	90
VLa and corresponding to *mlo*	4 + 9	0	0	0	0	0	4	0	0	2	16
VLa, Va13	4 + 10	na	na	3	0	11	6	35	25	3	43
Vk, Va7	6a + 6b	48	57	31	37	38	28	43	67	33	56
Va7, V(Ab)	6b + 6c	33	71	36	47	59	38	25	(100)*	50	80
VLa, Vk, + Va7	4 + 6a + 6b	59	41	44	27	38	22	28	58	24	76

* only two isolates; # no mildew in 1999.

REFERENCES

Mercer, P.C. (1999). Mildew of barley in Northern Ireland. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp. 56 - 59.

Mercer, P.C. (2000). Mildew of barley in Northern Ireland. *UK Cereal PathogenVirulence Survey 1999 Annual Report*, p 57.

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

YELLOW RUST OF BARLEY

G J HILTON, W C HUTTON and P L STIGWOOD

NIAB, Huntingdon Road, Cambridge CB3 0LE

Seven samples of barley yellow rust were received or collected in 2000, the highest number since 1987. The isolates obtained from the samples exhibited a range of virulence to the differential varieties. Some winter barley RL and RL candidate varieties appeared to possess reistance to a number of these isolates, whilst other varieties did not appear to possess any specific resistance.

INTRODUCTION

Barley yellow rust incidence was not high in 2000. However, seven samples were collected from untreated trial plots of winter barley, from three locations: Morpeth and Berwick-upon-Tweed in Northumberland, and Spalding in Lincolnshire. Levels of infection on these samples was generally high, with those from the Berwick site being exceptionally so, with sporulating pustules visible on flag leaves, stems and ears. Table 1 provides details of the resistance factors to *Puccinia striiformis* f. sp. *hordei* identified in the UK to date, the differential cultivars possessing the specific resistance, and the year of first detection in UK.

Table 1 Barley yellow rust resistance factors identified in the UK to date

BYR Factor	Type*	Differential Cultivars	BYV detected
BYR 1	O	Astrix, Atem	1960
BYR 2	O	Bigo, Varunda	)
	S	Mazurka	) 1972-1975)
BYR 3	?S	Triumph	1983

O = Overall
S = Seedling.

Overall resistances are effective at all growth stages, seedling resistances are ineffective at adult plant growth stages.

Information on each of the isolates obtained in 2000 is given in Table 2.

le 2 Barley yellow rust samples received in 2000

late le	Date collected/ received	Source variety [NIAB YR resistance rating]	Source location
)/1	16/6/00	Regina [2]	Berwick-upon-Tweed, Northumberland
0/2	20/6/00	Regina [2]	Spalding, Lincolnshire
)0/3	29/6/00	Leonie [4]	Morpeth, Northumberland
00/4	29/6/00	Regina [2]	Morpeth, Northumberland
00/5	29/6/00	Opal [5]	Berwick-upon-Tweed, Northumberland
00/6	29/6/00	Carola [4]	Berwick-upon-Tweed, Northumberland
00/7	29/6/00	Lagune [not in NIAB trials]	Berwick-upon-Tweed, Northumberland

Changes in the incidence and frequency of barley yellow rust virulence factors are difficult to determine from the limited number of isolates obtained in any one year, but the trends are presented in Table 3 below.

Table 3 Virulence factor frequency (%)

	'81	'82	'83	'84	'87	'89	'90	'91	'92	'93	'94	'95	'99	'00
BYV 1	100	100	100	100	100	100	100	100	100	100	100	100	100	86
BYV 2	81	96	87	100	100	100	0	100	100	100	100	100	100	71
BYV 3 †	-	-	17	86	22	75	0	0	0	0	100	0	100	71
No. of isolates	52	25	30	7	9	4	1	1	2	1	1	3	1	7

† Not included in tests before 1983.

No isolates were received in 1985, 1986, 1988, and 1996-1998 inclusive.

SEEDLING TESTS WITH 2000 AND HISTORIC ISOLATES

Seedling tests were carried out on current winter barley Recommended List (RL) and Recommended List candidate (RL cand.) varieties, using some of the isolates obtained in the 2000 survey, and using historic isolates from previous surveys. In this way an indication as to whether any of the varieties possessed any specific seedling resistance to *P. striiformis* could be gained. Details are given in Table 4. Methods were based on those described in Priestley et al (1984).

Table 4 Average infection types of winter cultivars, tested with isolates from 2000 and those from previous surveys

Variety		Isolate >	00/2	00/5	00/6	00/7	75/37	83/39	84/2	94/4	74/33	Adult plant tests*
		Virulence >	V0	V1,2,3	V1,2	V1,2,3	V3	V2	V2	V2,3	V2,3	
	Rating											%infection
ASTRIX [1]		Diff.	0.0	3.0	4.0	2.7	0.3	0.0	0.0	0.0	0.0	NIT
ATEM [1]		Diff.	0.0	4.0	3.0	2.0	0.0	0.0	0.2	0.3	0.0	4.5
BIGO [2]		Diff.	2.0	2.4	3.0	0.0	0.0	4.0	3.0	2.5	0.0	NIT
MAZURKA [2]		Diff.	1.0	3.0	3.0	2.0	0.6	3.0	2.4	2.4	3.0	22.4
VARUNDA [2]		Diff.	0.2	3.0	3.0	2.3	0.7	4.0	3.0	2.0	2.7	12.4
TRIUMPH [3]		Diff.	1.0	4.0	1.6	4.0	3.5	1.0	2.0	4.0	4.0	6.0
JACKPOT	6	RL cand.	2.0	4.0	4.0	3.0	1.5	1.0	4.0	2.8	3.4	6.8
JEWEL	8	RL	3.0	3.8	3.0	3.0	3.8	3.0	3.0	3.0	2.0	1.7
GLEAM	7	RL	2.0	4.0	3.0	1.8	4.0	3.0	4.0	3.0	3.2	1.7
AVENUE	7	RL	3.0	4.0	4.0	3.0	3.7	2.0	4.0	3.0	3.5	3.0
PEARL	6	RL	0.7	4.0	4.0	2.5	2.4	2.3	2.1	2.7	3.0	6.8
FANFARE	6	RL	0.5	3.5	4.0	3.5	2.9	3.0	3.0	2.6	3.0	1.6
MANITOU	5	RL	1.5	4.0	4.0	3.5	3.8	2.7	2.9	3.0	3.5	1.9
SCYLLA	(6)	RL cand.	2.0	4.0	4.0	4.0	3.0	3.0	4.0	3.0	3.5	4.8
MILENA	(2)	RL cand.	0.0	4.0	4.0	4.0	3.5	4.0	4.0	2.5	4.0	14.5

NIT = not in field tests
*Isolates **83/39, 84/2 & 94/4** used in adult plant field tests, 2000
Spr = spring variety, Diff = differential variety
Highlighted areas indicate variety x isolate interactions. They have no statistical significance.

Table 4. continued Average infection types of winter cultivars, tested with isolates from 2000 and those from previous surveys

		Isolate >	00/2	00/5	00/6	00/7	75/37	83/39	84/2	94/4	74/33	Adult plant tests*
Variety		Virulence >	V0	V1,2,3	V1,2	V1,2,3	V3	V2	V2	V2,3	V2,3	%infection
	Rating											
HAKA	8	RL	2.0	3.0	4.0	3.0	3.0	2.0	4.0	3.0	3.1	2.0
SUMO	5	RL	2.0	4.0	4.0	4.0	3.3	2.0	4.0	2.4	4.0	2.2
LEONIE	4	RL	2.0	4.0	4.0	4.0	4.0	2.0	4.0	2.4	3.5	7.8
OPAL	5	RL	2.0	4.0	4.0	4.0	3.0	2.0	4.0	2.8	3.5	5.0
CARAT	(6)	RL cand.	1.7	3.0	4.0	3.0	3.0	2.0	4.0	2.7	2.3	3.8
DIAMOND	(8)	RL cand.	2.0	4.0	4.0	4.0	4.0	2.0	3.8	3.0	2.7	1.4
REGINA	2	RL	2.0	4.0	4.0	4.0	3.9	3.0	3.0	3.0	3.6	21.3
INTRO	5	RL	4.0	4.0	4.0	3.0	4.0	3.0	4.0	4.0	3.5	4.5
ANTONIA	5	RL	3.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	3.4	3.3
VANESSA	3	RL	3.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	7.5
SIBERIA	3	RL	3.0	4.0	4.0	4.0	3.7	2.3	4.0	3.0	4.0	11.7
PASTORAL	8	RL	2.7	3.8	4.0	4.0	4.0	2.2	2.2	3.0	3.6	0.2
MUSCAT	4	RL	3.0	4.0	4.0	4.0	3.8	3.0	4.0	3.0	3.0	8.8
VERTIGE	7	RL	3.0	4.0	4.0	4.0	2.2	4.0	4.0	3.0	4.0	2.7
ANGELA	6	RL	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.4
FLUTE	9	RL	3.6	2.6	3.0	2.6	2.8	2.6	3.0	2.7	2.9	1.7
HELIGAN	5	RL	3.0	4.0	4.0	4.0	4.0	3.0	4.0	4.0	4.0	6.5
WHISPER	3	RL cand.	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.0	4.0	10.0
DEMON	(6)	RL cand.	3.0	4.0	4.0	4.0	4.0	3.0	4.0	3.0	3.5	6.0
CHAMOMILE	3	RL cand.	3.0	4.0	4.0	4.0	3.0	2.7	4.0	3.0	2.5	13.0
DERKADO (Spr)	8		0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.0	NIT
COOPER (Spr)	6		0.0	0.1	2.4	2.0	1.9	0.0	0.0	0.0	0.0	NIT
OPTIC (Spr)	8		0.0	2.6	2.0	0.0	0.3	0.0	1.0	1.4	2.3	0.1
DELIBES (Spr)	9		0.0	2.1	2.0	0.5	0.0	0.0	0.0	0.4	0.0	1.2
PRISMA (Spr)	7		0.0	0.0	0.0	0.0	0.9	0.0	1.0	0.0	1.0	0.2

NIT = not in field tests

*Isolates **83/39, 84/2 & 94/4** used in adult plant field tests, 2000

Spr = spring variety, Diff = differential variety

Highlighted areas indicate variety x isolate interactions. They have no statistical significance.

The results presented in Table 4 are based on one seedling test carried out in 2001, so they should be interpreted as early indications of variety x isolate interactions only. Similarly, the virulence of isolates is based on information gained only from these tests, and may differ from results from previous survey reports. Varieties have been grouped according to similar reactions to the isolates tested.

It appears from the tests that some of the winter barley varieties tested possess specific seedling resistance to *P. striiformis*, based on seedling test reactions of 2.0 or less. It should be noted that a great many of the reactions are 2.0, and it remains to be seen whether these reactions remain resistant in subsequent tests.

It is also evident from Table 4 that many winter barley varieties appear to possess no specific resistance. These varieties have NIAB yellow rust ratings ranging from 2 for Regina (very susceptible), to 9 for Flute (resistant), suggesting that resistance in the field is often based on adult plant or partial resistance, rather than specific seedling resistance.

A full set of *spring* barley Recommended List and Recommended List candidate varieties were not tested, due to space and time limitations. However, a number of varieties were tested, having been selected on the basis of giving variety x isolate interactions in previous tests (Meadway and Hutton, 1997). These varieties demonstrated a wide range of specific resistance to the isolates tested, with Derkado and Prisma giving resistant reactions to all isolates tested.

From the results from this year's seedling tests, it would appear that it would be preferable for breeders to use partial resistance to barley yellow rust, rather than specific resistance. This appears to be the most reliable source of resistance, as evidenced by the high ratings of some varieties (e.g Flute = 9, Pastoral = 8) which do not appear to possess any specific resistance.

The higher number of barley yellow rust samples received in 2000 should serve as a warning to growers that the potential still exists for an epidemic, particularly since susceptible varieties (NIAB rating of 3 or less) still make up a significant proportion of the barley area.

REFERENCES

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

Meadway, M H and Hutton W C (1997). Yellow rust of barley. *U K CerealPathogen Virulence Survey 1996 Annual Report*, pp 43-47.

…WN RUST OF BARLEY

…L JONES

…titute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion
…Y23 3EB

In glasshouse tests of winter barleys, only cvs Jewel and Whisper, expressed resistance as adult plants to all brown rust isolates. In similar tests, several spring barleys expressed effective overall or adult plant resistance to the isolates. In field nurseries, where infection levels on the susceptible cultivars were generally much lower than in glasshouse tests, a number of winter barleys were infected at low levels. Cultivars Angela, Intro and Avenue were classified as resistant. A number of spring barleys also expressed resistance in the field.

SEEDLING TESTS WITH YEAR 2000 ISOLATES

Only six samples, all from winter barleys, were received in year 2000. Isolates cultured from them were tested on a set of ten cultivars (Table 1) which carry different, identified Pa genes for resistance to *Puccinia hordei*.

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

Cultivar	BBR Factor	Gene symbol	Ranking for octal notation
Sudan	1	Pa_1	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
Trimph	10	Pa_{10}	10

Results

Four different, previously identified, virulence combinations (races) were detected (Table 2). Only resistance conferred by Cebada Capa (Pa_7) was effective against all isolates.

The results presented in Table 4 are based on one seedling test carried out in 2001, so they should be interpreted as early indications of variety x isolate interactions only. Similarly, the virulence of isolates is based on information gained only from these tests, and may differ from results from previous survey reports. Varieties have been grouped according to similar reactions to the isolates tested.

It appears from the tests that some of the winter barley varieties tested possess specific seedling resistance to *P. striiformis*, based on seedling test reactions of 2.0 or less. It should be noted that a great many of the reactions are 2.0, and it remains to be seen whether these reactions remain resistant in subsequent tests.

It is also evident from Table 4 that many winter barley varieties appear to possess no specific resistance. These varieties have NIAB yellow rust ratings ranging from 2 for Regina (very susceptible), to 9 for Flute (resistant), suggesting that resistance in the field is often based on adult plant or partial resistance, rather than specific seedling resistance.

A full set of *spring* barley Recommended List and Recommended List candidate varieties were not tested, due to space and time limitations. However, a number of varieties were tested, having been selected on the basis of giving variety x isolate interactions in previous tests (Meadway and Hutton, 1997). These varieties demonstrated a wide range of specific resistance to the isolates tested, with Derkado and Prisma giving resistant reactions to all isolates tested.

From the results from this year's seedling tests, it would appear that it would be preferable for breeders to use partial resistance to barley yellow rust, rather than specific resistance. This appears to be the most reliable source of resistance, as evidenced by the high ratings of some varieties (e.g Flute = 9, Pastoral = 8) which do not appear to possess any specific resistance.

The higher number of barley yellow rust samples received in 2000 should serve as a warning to growers that the potential still exists for an epidemic, particularly since susceptible varieties (NIAB rating of 3 or less) still make up a significant proportion of the barley area.

REFERENCES

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

Meadway, M H and Hutton W C (1997). Yellow rust of barley. *U K CerealPathogen Virulence Survey 1996 Annual Report*, pp 43-47.

BROWN RUST OF BARLEY

E R L JONES

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

In glasshouse tests of winter barleys, only cvs Jewel and Whisper, expressed resistance as adult plants to all brown rust isolates. In similar tests, several spring barleys expressed effective overall or adult plant resistance to the isolates. In field nurseries, where infection levels on the susceptible cultivars were generally much lower than in glasshouse tests, a number of winter barleys were infected at low levels. Cultivars Angela, Intro and Avenue were classified as resistant. A number of spring barleys also expressed resistance in the field.

SEEDLING TESTS WITH YEAR 2000 ISOLATES

Only six samples, all from winter barleys, were received in year 2000. Isolates cultured from them were tested on a set of ten cultivars (Table 1) which carry different, identified Pa genes for resistance to *Puccinia hordei*.

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

Cultivar	BBR Factor	Gene symbol	Ranking for octal notation
Sudan	1	Pa_1	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
Trimph	10	Pa_{10}	10

Results

Four different, previously identified, virulence combinations (races) were detected (Table 2). Only resistance conferred by Cebada Capa (Pa_7) was effective against all isolates.

Table 2 Races identified from 2000 isolates

Isolate	Origin (cultivar/county)	Race octal	BBV factors
BRS-00-01	Regina, Suffolk	273	1,2,4,5,6,8
BRS-00-02	Regina, Suffolk	1677	1,2,3,4,5,6,8,9,10
BRS-00-03	Regina, Suffolk	1677	1,2,3,4,5,6,8,9,10
BRS-00-04	Pearl, Lancs	1657	1,2,3,4,6,8,9,10
BRS-00-05	Heligan, Notts	1673	1,2,4,5,6,8,9,10
BRS-00-06	Heligan, Notts	1673	1,2,4,5,6,8,9,10

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 cultivars on the NIAB Recommended Lists of winter and spring barleys as well as the standard set of seedling differential cultivars. Two replicates of each cultivar were inoculated with one each of the following isolates:

Isolate	BBV-	(Race octal)	Origin
BRS-00-04	1,2,3,4,6,8,9,10	(1657)	cv. Pearl, Lancs
BRS-00-02	1,2,3,4,5,6,8,9,10	(1677)	cv. Regina, Suffolk
BRS-00-01	1,2,4,5,6,8	(273)	cv. Regina, Suffolk

The plants were inoculated, incubated and assessed using methods described previously (Jones and Clifford, 1996).

Seedling tests

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

Results

Winter barleys (Table 3)

Cultivars are classified into groups on the basis of similarities in the pattern of their adult plant responses to the isolates. All cultivars were susceptible as seedlings.

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

Group 2: The cultivars were susceptible as adult plants to isolate BRS-00-01 (race octal 273) only. This isolate carries fewer virulence factors than isolates BRS-00-04 or BRS-00-02. Similar tests in previous years have shown a number of cultivars, including some

of those in the current tests, to be susceptible to isolates classified as race octal 273 but to be resistant to isolates carrying additional virulence factors. The reasons for this are unclear.
Group 3: As adult plants, cvs Jewel and Whisper showed more resistance to isolate BRS-00-01 than cultivars in Group 2.

Spring barleys (Table 4)

Cultivars are again classified into groups on the basis of similarities in the adult plant x isolate interactions.

Group 1: Cultivars highly susceptible.
Group 2: Included within this group are some of the differential cultivars from the standard set which carry known specific resistances. With the exception of cv. Bolivia (BBR-6), cultivars within this group were shown in seedling tests to be susceptible to isolates carrying the corresponding virulence factors (BBV-3, -9, -10). Cultivar Bolivia expressed resistance as an adult plant to isolate BRS-00-01 (that carries BBV-6) although it was seedling susceptible.
Group 3: Cultivars Prestige and Neruda were susceptible only to the widely virulent isolate BRS-00-02.
Group 4: The adult plant resistance of cv. Egypt 4 (BBR-8) was overcome only by isolate BRS-00-01 and maintained its adult plant resistance even against other isolates that carried corresponding virulence as demonstrated in seedling tests. This confirmed previous years' tests showing that Egypt 4 maintains adult plant resistance against isolates carrying the corresponding virulence factor (although previously BRS-00-01 was not used). Cultivar Otira displayed a similar pattern of responses.
Group 5: Several of the current NIAB recommended spring barleys expressed a range of quantitative, resistant or mixed resistant responses to all isolates as adult plants. Some were differentiated by their seedling responses. The differential cvs Peruvian (BBR-2) and Quinn (BBR-5) were susceptible as seedlings to isolates carrying the corresponding virulence factors but as adult plants they were resistant to these isolates.

ADULT PLANT FIELD ISOLATION NURSERIES

Winter and spring barleys were sown during the 1999-2000 season. They included cultivars on the NIAB Recommended Lists of winter and spring barleys, outmoded cultivars and potential new cultivars. Inoculum, comprising mixed isolates of three races, was introduced artificially into the nurseries. The isolates were those used in 1999 glasshouse tests (Jones, 2000), namely:

BRS-99-13 (BBV-1,2,4,5,6,8)	cv. Muscat, Yorkshire
BRS-97-2 (BBV-1,2,3,4,6,8,9,10)	cv. Muscat, Northumberland
BRS-97-27 (BBV-1,2,4,6,8,9,10)	cv. Fighter, Lincolnshire

Results

Winter barley (Table 5)

Reasonable levels of brown rust built up on the susceptible cultivars but natural contamination of the nursery with *Rhynchosporium* pathotypes made assessment of rust infection on some cultivars difficult, particularly towards the end of the season. 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.

The cultivars displayed a range of quantitative responses to the isolate mixture with infection levels being generally much lower than in adult plant tests in the glasshouse. Three cvs, Angela, Intro and Avenue expressed low levels of infection of a mixed resistant type. Previously, (Jones, 2000) Angela and Intro had been very susceptible in glasshouse tests to each of the isolates comprising the current inoculum mixture.

Spring barley (Table 6)

Disease levels were again generally lower than in glasshouse tests. Cultivars expressed a range of quantitative, susceptible and resistant responses to the mixture of isolates. Of those showing a resistant reaction cvs Chariot, Saloon, Delibes, Static and Berwick had been examined previously. They gave similar results to previous tests. Currently, cv. Chariot expressed high levels of infection but of a mixed resistant reaction, whereas previous glasshouse tests had shown it to be susceptible to each of the isolates used in the current field test (Jones, 2000). Cultivars Brise, Tavern and County were highly resistant confirming their NIAB ratings for brown rust resistance.

ACKNOWLEDGEMENT

I am grateful to Dr Tim Carver for his comments on this report.

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. (2000). Brown rust of barley. *UK Cereal Pathogen Virulence Survey 1999 Annual Report*, pp.61-68

Table 3 *Reactions of winter barley cultivars, adult plants and seedlings ( ), to specific isolates of *Puccinia hordei* in glasshouse tests

Isolate / Cultivar [NIAB rating]		Group	BRS-00-04 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-00-02 (BBV-1,2,3,4,5,6,8,9,10) Race octal 1677			BRS-00-01 (BBV-1,2,4,5,6,8) Race octal 273		
Muscat	[6]	1	50	S	(S)	50	S	(S)	50	S	(S)
Leonie	[5]		48	S	(S)	50	S	(S)	50	S	(S)
Siberia	[5]		50	S	(S)	30	S	(S)	40	S	(S)
Pastoral	[4]		43	S	(S)	23	S	(S)	33	S	(S)
Vertige	[6]		45	S	(S)	35	S	(S)	20	S	(S)
Jackpot	[5]		40	S	(S)	33	S	(S)	43	S	(S)
Angela	[7]		38	S	(S)	33	S	(S)	28	S	(S)
Regina	[6]		35	MS	(S)	33	MS	(S)	25	S	(S)
Opal	[4]	2	23	R	(S)	38	R	(S)	48	S	(S)
Gleam	[5]		33	MR	(S)	50	MR	(S)	45	S	(S)
Avenue	[7]		55	R	(-)	45	R	(S)	40	S	(S)
Sumo	[7]		18	R	(S)	30	R	(S)	38	MS	(S)
Pearl	[7]		23	MR	(S)	33	MR	(S)	25	S	(S)
Intro	[7]		25	R	(S)	70	MR	(S)	30	MS	(S)
Antonia	[7]		15	R	(S)	45	MR	(S)	25	S	(S)
Heligan	[6]		25	R	(S)	30	MR	(S)	20	M S	(S)
Jewel	[7]	3	20	R	(S)	25	R	(S)	25	MR	(S)
Whisper	[6]		20	R	(S)	25	R	(S)	20	MR	(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 cv., classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant

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

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

Isolate / Cultivar [NIAB rating]		Group	BRS-00-04 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-00-02 (BBV-1,2,3,4,5,6,8,9,10) Race octal 1677			BRS-00-01 (BBV-1,2,4,5,6,8) Race octal 273		
Pewter	[4]	1	60	S	(S)	60	S	(S)	60	S	(S)
Riviera	[5]		40	S	(S)	55	S	(S)	50	S	(S)
Gold	BBR-4		55	S	(S)	43	S	(S)	55	S	(S)
Sudan	BBR-1		50	S	(S)	55	S	(S)	35	S	(S)
Optic	[8]	2	60	S	(S)	40	S	(S)	35	R	(R)
Trumpf	BBR-10		60	S	(S)	55	S	(S)	43	R	(R)
Hordeum 2596	BBR-9		50	S	(S)	10	S	(S)	38	R	(R)
Ribari	BBR-3		25	S	(S)	45	S	(S)	14	R	(R)
Bolivia	BBR-6		15	MS	(S)	30	MS	(S)	20	R	(S)
Prestige		3	30	R	(MS)	45	S	(MS)	45	R	(R)
Neruda			38	R	(MR)	65	S	(MS)	25	R	(R)
Otira		4	55	R	(MS)	40	R	(S)	40	S	(S)
Egypt 4	BBR-8		45	MR	(MS)	43	MR	(S)	40	MS	(S)
Delibes	[8]	5a	13	R	(S)	10	R	(S)	10	R	(R)
Saloon	[6]		50	R	(S)	23	R	(MS)	20	R	(R)
Decanter	[7]		40	R	(MS)	43	R	(S)	28	R	(R)
Peruvian	BBR-2	5b	45	R	(S)	60	MR	(S)	25	R	(S)
County	[9]	5c	0		(MR)	45	R	(S)	0		(R)
Brise			50	R	(MR)	43	R	(S)	35	R	(R)
Cellar	[8]	5d	30	R	(MR)	65	MR	(MR)	20	R	(R)
Berwick			38	MR	(MR)	45	MR	(MR)	28	R	(R)
Tavern	[9]		18	R	(MR)	60	R	(MR)	10	R	(R)
Static	[8]		35	R	(MR)	60	R	(MR)	30	R	(R)
Cebada Capa	BBR-7		23	R	(R)	8	R	(R)	3	R	(R)
Quinn	BBR-5	5e	0		(R)	23	R	(S)	13	MR	(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 cv.,
classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant
*Seedlings assessed on reaction type on 1st leaf.
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 5 *Reactions of winter barley cultivars to brown rust in a field nursery in 2000

Cultivar [NIAB rating]		% Infection	Reaction type
Vanessa	[4]	20	S
Vertige	[6]	15	S
Manitou	[4]	13	S
Hanna	[4]	13	S
Leonie	[5]	11	S
Pastoral	[4]	11	S
Opal	[4]	11	S
Siberia	[5]	10	S
Melanie	[3]	9	S
Artist		8	S
Jewel	[7]	8	S
Gleam	[5]	7	S
Regina	[6]	7	S
Heligan	[6]	7	S
Fanfare	[7]	7	S
Halcyon	[6]	6	S
Flute	[8]	6	S
Chamomile	[7]	6	S
Jackpot	[5]	3	S
Rifle		3	S
Whisper	[6]	2	S
Muscat	[6]	2	S
Sumo	[7]	1	S
Antonia	[7]	1	S
Pearl	[7]	0.5	S
Angela	[7]	3	MR
Intro	[7]	2	MR
Avenue	[7]	2	MR

*Mean of 4 replicates, 2 assessment dates
0-2 type reaction – resistant (R) 3-4 type reaction – susceptible (S)
When more than one reaction type is expressed by a single cv., classification is based on the prevalent response.
MR = mixed resistant
*Seedlings assessed on reaction type on 1st leaf.
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 6 *Reactions of spring barley cultivars to *Puccinia hordei* in a field nursery in 2000

Cultivar [NIAB rating]		BBR factor	% Infection	Reaction type
Riviera	[5]		24	S
Prestige			23	S
Quinn		5	23	S
Chalice	[6]		23	S
Pewter	[4]		19	MS
Century			18	S
Dandy	[5]		17	S
Trumpf		10	17	S
Annabell			14	S
Neruda			14	MS
Otira			13	MS
Cellar	[8]		11	MS
Decanter	[7]		9	MS
Prisma	[5]		7	S
Simon		3	6	S
Optic	[8]		6	MS
Chime	[8]		4	S
Chariot	[6]		22	MR
Berwick			15	MR
Saloon	[6]		15	MR
Brise			10	R
Static	[8]		6	R
Tavern	[9]		5	R
County	[9]		0.1	R
Delibes	[8]		0	

*Mean of 4 replicates, final 2 assessment dates
0-2 type reaction – resistant (R) 3-4 type reaction – susceptible (S)
When more than one reaction type is expressed by a single cv., classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant
[ ] NIAB rating: 1 = susceptible; 9 = resistant

RHYNCHOSPORIUM OF BARLEY

E R L JONES and A C NEWTON†

Institute of Grassland and Environmental Research, Plas Gogerddan, Aberystwyth, Ceredigion SY23 3EB
†Scottish Crop Research Institute, Invergowrie, Dundee

Glasshouse tests identified several winter barleys as carrying the race specific resistance BRR-2. Cultivar Leonie was susceptible only to an isolate carrying BRV-5. In field tests, where infection levels were generally lower on winter barleys than in corresponding glasshouse tests, some winter barley cultivars expressed good levels of resistance. Spring barley field nurseries at IGER and SCRI identified cv. Pewter as being highly resistant.

SEEDLING TESTS WITH YEAR 2000 ISOLATES

Leaf blotch levels were at one of their highest in the 1999-2000 season. A large proportion (43%) of the *Rhynchosporium*-infected leaf samples received were, as in 1999, from the widely grown winter barley Regina. They were collected from crops which had up to 50% of their flag leaf area infected. The remainder of the 62 samples, including 10 received as agar cultures from Northern Ireland, were from a range of winter (26) and spring (8) barleys. One was of unknown cultivar origin. The geographic origins of the samples are given in Table 1.

Table 1 Geographic origins (county) of *Rhynchosporium* samples received in 2000

County of origin	No. of samples	County of origin	No. of samples
Tayside	15	Devon	2
Co. Down	10	Dorset	1
Suffolk	4	Cornwall	1
Warks.	3	Wilts.	1
Northumberland	7	Mid-Glam.	1
Northants.	3	Norfolk	1
Glos.	3	Cleveland	1
Kent	2	S. Yorks.	1
Sussex	2	Worcs.	1
Somerset	2	Humberside	1

Isolates from 40 of the samples were tested on seedlings of a set of differential cvs (Table 2).

Table 2 Differential test cultivars for *Rhynchosporium secalis*

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

Results

Virulence was identified to all the specific resistances carried by the test cultivars (Table 3).

Table 3 Frequencies of individual virulences, 1990-2000

Year	BRV-								No. of isolates
	8	7	6	5	4	3	2	1	
2000	0.05	0.70	0.05	0.05	0.78	1.00	0.75	0.75	40
1998	0.03	0.42	0.06	0.22	0.67	1.00	0.72	0.72	36
1996	-	0.68	0.18	0.39	0.71	1.00	0.61	0.61	28
1994	-	0.85	0.07	0.15	0.97	0.99	0.88	0.88	67
1992	-	0.50	0.07	0.10	0.86	0.97	0.40	0.40	30
1990	-	0.54	0.23	0.30	0.76	0.92	0.23	0.23	13

Two isolates carried virulence to cv. Digger (BRR-8). One of these, RS-00-20, was cultured from a leaf sample of cv. Livet collected at SCRI, Dundee. Previous tests have shown cv. Livet also to carry the specific resistance BRR-8. The other cv. Digger-virulent isolate was cultured from cv. Avenue (unknown resistance factors) grown at Cockle Park, Northumberland. As in previous years BRV-5 and BRV-6 were at a low frequency, being found in only two isolates, both cultured from cv. Pipkin (BRR-5).

The virulences identified from the isolates occurred in various combinations (Table 4). The virulence combinations gave a range from two virulence factors (octal race 14), in the six isolates tested from Northern Ireland, to six virulence factors found in a single isolate (octal race 317). Fifty-five percent of the isolates were classified as octal race 117, capable of overcoming the specific resistance BRR-2. This resistance is carried by many of the current winter barley cultivars including cv. Regina from which many samples were received.

Table 4 Virulence factor combinations identified from 2000 isolates

No. of	Differential cultivars in linear order								Race
isolates	Digger	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	octal
6	0	0	0	0	1	1	0	0	14
1	0	1	0	0	1	1	0	0	114
1	1	1	0	0	1	1	0	0	314
1	0	1	1	1	0	1	0	0	164
1	0	1	1	1	1	1	0	0	174
2	0	0	0	0	0	1	1	1	7
4	0	0	0	0	1	1	1	1	17
1	0	1	0	0	0	1	1	1	107
22	0	1	0	0	1	1	1	1	117
1	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 cultivars on the NIAB Recommended List of winter and spring barleys as well as the standard set of seedling differential cultivars. Two replicates of each cultivar were inoculated with one of each of the following isolates:

Isolate	†BRV-(race octal)	Origin
RS-00-19	3,5,6,7 (164)	cv. Pipkin, Tayside
RS-00-02	1,2,3,4,7 (117)	cv. Regina, Suffolk
RS-00-20	3,4,7,8 (314)	cv. Livet, Tayside

† identified in seedling tests

Plants were inoculated using methods described previously (Jones, Clifford and Newton, 1996) and assessed on percentage flag leaf area infected.

Seedling tests

Seedlings of the cultivars, grown in a spore-proofed glasshouse to the second leaf stage, were inoculated with the same isolates and incubated under the same conditions as the adult plants. They were assessed by infection levels on the second leaf and classified as resistant (R) or susceptible (S).

Results

Winter barleys (Table 5):

Cultivars are grouped within Table 5 on the basis of similarities in the patterns of their responses to the isolates. Grouping does not necessarily imply that cultivars within a group carry a common resistance factor(s).

Group 1: Cultivars were susceptible as adult plants and seedlings to all isolates although quantitative differences in levels of infection were evident between them. The high levels of disease on seen some cultivars in these glasshouse tests are much greater than those seen on the same cultivars in field nursery tests (Table 7).
Group 2: These cultivars were susceptible to isolate RS-00-02 (octal race 117) but generally showed good resistance to the other isolates. Nevertheless, as adult plants some cultivars included here were infected at low levels by isolates RS-00-19 and RS-00-20. The differential cultivar (BRR-2) is included in this group.
Group 3: The differential cultivar Igri (BRR-4) was susceptible to isolates RS-00-02 and RS-00-20, both of which carry virulence factor (BRV-4). Nevertheless, RS-00-20 gave lower infection levels than RS-00-02.
Group 4: The specific resistance BRR-5 has previously been seen to be ineffective at later growth stages even to isolates that do not carry corresponding virulence (Jones and Clifford, 1982). In the current tests, cv. Leonie was susceptible as an adult plant to all three isolates although in seedling tests its resistance was effective against the two isolates that lack virulence factor BRV-5.
Group 5: Cultivar Manitou, which has shown effective resistance in similar tests over a number of years, was infected at low levels in the current test.

Spring barleys (Table 6):

The majority of the commercial cultivars were susceptible to all isolates. Within Table 6, cultivars are grouped on the basis of similarities in the pattern of their seedling responses to the isolates.

Group 1: Cultivars were generally highly susceptible. These included cv. Pewter, which expressed high levels of resistance in a field disease nursery (Table 8) and which has a NIAB rating of 9. Cultivar Tavern was resistant as an adult plant only to isolate RS-00-20.
Group 2: Seedlings of the cultivars included here showed a resistant reaction type to isolate RS-00-02 but gave a susceptible seedling reaction to the other two isolates. The differential cv. Armelle was susceptible as an adult plant only to isolate RS-00-02. Cultivar Otira displayed a similar pattern

of responses as cv. Armelle in seedling tests, but was susceptible in adult plant tests to all three isolates.

Group 3: Cultivar Century, like cv. La Mesita (BRR-5), was susceptible as an adult plant to isolates RS-00-02 and RS-00-20, although seedling tests suggest that these isolates do not carry virulence factor BRV-5. In seedling tests both cultivars were susceptible to isolate RS-00-19, which does carry this virulence factor.

Group 4: The specific resistance (BRR-6) of cv. Osiris was overcome by isolate RS-00-19 in seedling tests although in adult plant tests it infected it at very low levels .

Group 5: Cultivar Digger (BRR-8), virulence to which has remained at a very low frequency in the pathogen population (Table 3), was susceptible as a seedling and adult plant only to isolate RS-00-20 which carries virulence factor BRV-8.

ADULT PLANT FIELD ISOLATION NURSERIES AT IGER

Winter and spring barley nurseries were sown during the 1999-2000 season on a site conducive to the development of the disease which was allowed to develop from endemic inoculum. Included in the tests were cvs on NIAB Recommended Lists of winter and spring barleys, potential new cvs, and cvs carrying known specific resistances and used as differentials in seedling tests.

Results

Winter barley (Table 7):

Reasonable levels of disease built up on the susceptible cvs (assessed by percentage leaf area infected). Cultivars differed in the levels of disease they developed, presumably because they showed different levels of quantitative resistance to naturally occurring pathotypes. Generally, infection levels were much lower than on the corresponding cvs in glasshouse tests (Table 5). Several cvs, including Manitou, expressed high levels of resistance; Manitou has consistently shown resistance over a number of years.

Spring barley (Table 8):

In a season conducive to the development of the disease, high levels of infection built up on the susceptible cvs. Of those on the NIAB Recommended List, only the resistance of cv. Pewter was effective; the remainder were relatively susceptible. The differential cvs Digger (BRR-8), Osiris (BRR-6) and Armelle (BRR-1) were resistant to the naturally-occurring pathotypes which infected the nursery.

ADULT PLANT FIELD NURSERY AT SCRI

A nursery, comprising varieties from the 2000 NIAB Recommended List of spring barleys, together with cultivars carrying known specific resistances, was sown during the spring of 2000. Cultivars within the nursery became infected with naturally occurring pathotypes.

Results

Assessments of percentage leaf area infected were made throughout the season and results are given in Table 9. High levels of disease built up on the susceptible cultivars. They expressed a range of quantitative responses to the pathotypes with cultivar rankings generally confirming those in the spring barley field nursery at IGER as well as their NIAB disease ratings.

Cultivar Pewter, together with those cultivars carrying known specific resistances and which are used in seedling tests to identify virulence factors in the pathogen, showed high levels of resistance.

ACKNOWLEDGEMENT

I am grateful to Dr Tim Carver (IGER) for his comments on this report.

REFERENCES

Jones, E.R.L., Clifford, B.C. and Newton, A.C. (1996). *Rhynchosporium* of barley. *UK Cereal Pathogen Virulence Survey 1995 Annual Report*, pp.56-63.

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

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

Cultivar/isolate [NIAB rating]	Group	RS-00-19 (Race octal 164) BRV-3,5,6,7	RS-00-02 (Race octal 117) BRV-1,2,3,4,7	RS-00-20 (Race octal 314) BRV-3,4,7,8
Vertige [5]	1	80 (S)	70 (S)	70 (S)
Antonia [8]		70 (S)	70 (S)	28 (S)
Pastoral [8]		70 (S)	65 (S)	20 (S)
Jewel [8]		60 (S)	50 (S)	50 (S)
Sumo [5]		43 (S)	75 (S)	43 (S)
Fanfare [8]		40 (S)	53 (S)	43 (S)
Flute [8]		38 (S)	45 (S)	35 (S)
Muscat [8]		25 (S)	50 (S)	35 (S)
Pearl [8]		23 (S)	40 (S)	35 (S)
Athene BRR-3		65 (S)	75 (S)	80 (S)
Pirate BRR-7		15 (S)	33 (S)	10 (S)
Intro [6]	2	0 (R)	70 (S)	0 (R)
Regina [8]		0 (R)	60 (S)	0.5 (R)
Whisper [6]		2 (R)	60 (S)	0 (R)
Heligan [7]		2 (R)	58 (S)	0 (R)
Siberia [7]		0 (R)	40 (S)	0 (R)
Angela [8]		10 (R)	38 (S)	8 (R)
Gleam [7]		5 (R)	35 (S)	0 (R)
Jackpot [8]		0 (R)	33 (S)	0 (R)
Chamomile [8]		0 (R)	30 (S)	0 (R)
Astrix BRR-2		3 (R)	70 (S)	0 (R)
Igri BRR-4	3	0 (R)	45 (S)	14 (S)
Leonie [9]	4	43 (S)	35 (R)	15 (R)
Manitou [9]	5	10 (S)	3 (R)	8 (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)
[ ] NIAB rating: 1 = susceptible; 9 = resistant

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

Cultivar/Isolate [NIAB rating]		Group	RS-00-19 (Race octal 164) BRV-3,5,6,7		RS-00-02 (Race octal 117) BRV-1,2,3,4,7		RS-00-20 (Race octal 314) BRV-3,4,7,8	
Prestige		1	85	(S)	80	(S)	80	(S)
Neruda [3]			80	(S)	80	(S)	80	(S)
Brise [3]			75	(S)	80	(S)	75	(S)
Annabell			75	(S)	85	(S)	80	(S)
Cellar [4]			75	(S)	80	(S)	60	(S)
Berwick [6]			60	(S)	75	(S)	60	(S)
Pewter [9]			55	(S)	28	(S)	60	(S)
Chariot [4]			50	(S)	53	(S)	40	(S)
Tavern [6]			25	(S)	60	(S)	1	(S)
Armelle	BRR-1	2	0	(R)	70	(S)	0	(R)
Otira			50	(R)	70	(S)	30	(R)
Century		3	70	(S)	70	(R)	15	(R)
La Mesita	BRR-5		75	(S)	25	(R)	48	(R)
Osiris	BRR-6	4	5	(S)	2	(R)	0	(R)
Digger	BRR-8	5	0	(R)	0	(R)	30	(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)
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 7 *Infection of winter barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2000

Cultivar	[NIAB rating]	Mean % infection
Vertige	[5]	40
Pipkin		36
Sumo	[5]	31
Igri	BRR-4	28
Otter		25
Astrix	BRR-2	25
Avenue	[6]	25
Siberia	[7]	22
CPBTB27		21
Heligan	[7]	21
Halcyon	[5]	21
Rifle		21
Whisper	[6]	19
Opal	[7]	18
Flute	[8]	18
Pastoral	[8]	17
Gleam	[7]	16
Intro	[6]	16
Chamomile	[8]	15
Melanie	[8]	13
Pirate	BRR-7	13
Vanessa	[8]	12
Regina	[8]	11
Antonia	[8]	10
Athene	BRR-3	9
Leonie	[9]	9
Artist		8
Jewel	[8]	7
Pearl	[8]	5
Fanfare	[8]	5
Hanna	[8]	3
Muscat	[8]	2
Carat	[8]	0.7
Jackpot	[8]	0.5
Angela		0.4
Manitou	[9]	0.2

*Mean of 3 replicates, 2 assessment dates
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 8 *Infection of spring barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2000

Cultivar	[NIAB rating]	Mean % infection
Cellar	[4]	65
Optic	[3]	64
Chariot	[4]	60
Brise	[3]	60
Annabell		58
Neruda	[3]	56
Static	[5]	56
Berwick	[6]	54
Chime	[5]	52
Otira		51
Saloon	[5]	46
Chalice	[6]	46
Riviera	[6]	46
Prestige		44
Decanter	[5]	42
Prisma	[6]	35
Tavern	[6]	35
Delibes	[7]	32
County	[6]	27
Dandy	[7]	26
Century		18
Pewter	[9]	3
La Mesita	BRR-5	21
Armelle	BRR-1	6
Osiris	BRR-6	0.5
Digger	BRR-8	0.5

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

Table 9 *Infection of barley cultivars to *Rhynchosporium* in a SCRI field nursery in 2000

Cultivar	[NIAB rating]	Mean % infection
Neruda	[3]	41
Chariot	[4]	41
Optic	[3]	40
Cellar	[4]	39
Brise	[3]	39
Annabell		37
Chime	[5]	35
Saloon	[5]	35
Chalice	[6]	33
Prestige		31
County	[6]	30
Static	[5]	30
Decanter	[5]	30
Delibes	[7]	29
Prisma	[6]	29
Riviera	[6]	25
Century		25
Berwick	[6]	22
Tavern	[6]	21
Dandy	[7]	21
Otira		14
Livet		10
Digger	BRR-8	5
La Mesita	BRR-5	5
Pewter	[9]	4
Osiris	BRR-6	1
Armelle	BRR-1	1
Athene	BRR-3	0.02
Igri	BRR-4	0.01
Pirate	BRR-7	0
Astrix	BRR-2	0

SED = 3.08

*Mean of 4 replicates, 4 assessment dates

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

NET BLOTCH OF BARLEY

E R L JONES

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

In adult plant glasshouse tests, winter barleys showed quantitative variation in levels of net blotch folowing inoculation with a mixture of isolates. Several of the current NIAB Recommended List cultivars showed low levels of infection. These included cv. Regina which was infected at lower levels than in 1998 and 1999. Several of the spring barley cultivars were heavily infected and only cv. County expressed good resistance.

The geographic and cultivar origins of the nine net blotch samples received in year 2000 are given in Table 1.

Table 1 Geographic origins (county) of the 2000 net blotch samples

County	Cultivar (No. of samples)
Suffolk	Regina (2), Vertige
Lincs	Regina
Essex	Regina
Hants	Regina
Herts	Regina
Notts	Heligan
Northants	Regina

The higher than expected levels of net blotch seen in some cv. Regina crops (up to 12% flag leaf area infected) sampled in 1998 and 1999 were not repeated. In 2000, crops from which infected leaves were received had less than 3% flag leaf infected.

The samples received were not tested individually on the standard set of seedling differential cultivars, but a mixture of all the isolates were inoculated onto seedlings and adult plants of a number of cultivars.

GLASSHOUSE TESTS WITH 2000 ISOLATES

Adult plant tests

Winter and spring barley cultivars were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included winter and spring barleys cultivars on the NIAB Recommended Lists (2000), potential new cultivars and the standard set of seedling differential cultivars. Two replicates of each cultivar were inoculated with a spore suspension of a mixture of isolates obtained from the nine samples received in 2000.

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 12 days. Assessments were made of percentage flag leaf area infected.

Seedling tests

Seedlings of the same cultivars used in adult tests 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 = 0-2 (R) or susceptible = 3-4 (S).

Results

Disease symptoms on adult plants were mainly of a blotching or striping type whereas on susceptible seedlings they were generally of a netting type but of a spotting type on the more resistant cultivars.

Winter barleys (Table 2):

Infection levels on adult plants of the susceptible cultivars were generally lower than those expressed in similar tests in previous seasons. Cultivars showed quantitative variation in the level of disease developed with several winter barleys showing good levels of resistance. These included cv. Pearl which has a NIAB disease rating of 5 but which has also only shown low levels of infection in previous adult plant glasshouse tests. Conversely, cv. Leonie, which was infected at relatively high levels and was also susceptible in seedling tests, has been very resistant in NIAB trials (disease rating 9).

Isolates cultured from samples received in the 1998 and 1999 surveys showed increased virulence on the previously resistant cv. Regina which reflected the higher than expected levels of disease on some field crops of this variety during those seasons. Net blotch infected leaves of cv. Regina from the current year's survey were taken from crops that were generally less heavily infected. This may have contributed to the finding that inoculum from the year 2000 collection gave lower levels of infection on cv. Regina than was seen in similar tests in the previous two years.

Cultivars Angela, Siberia and Vertige were seedling resistant, the former also being resistant in 1999 tests. Of the differential cultivars, only CI 9518 was susceptible as a seedling.

Spring barleys (Table 3):

The spring barleys generally became more heavily infected than the winter barley cultivars. They showed quantitative variation in levels of disease development with only cv. County expressing a high level of resistance. Seedlings of the differential cultivars CI 739, CI 4979, CI 5401 and Proctor were susceptible to the mixed inoculum employed. Thus, based on the seedling responses of the differential cultivars, the mixture of pathotypes used in the tests carried virulences 1,4,8,9,10.

ACKNOWLEDGEMENT

I am grateful to Dr Tim Carver (IGER) for his comments on this report.

REFERENCE

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

Table 2 *Reactions of winter barley cultivars, adult plants and seedling, to a mixture of net blotch isolates in glasshouse tests

Cultivar [NIAB Rating]		Differential code number	Adult plant % infection	†Seedling reaction
Gleam	[4]		38	S
Intro	[7]		30	S
Fanfare	[7]		28	S
Leonie	[9]		20	S
Whisper	[7]		20	S
Antonia	[8]		15	S
Avenue	[7]		15	S
Angela	[5]		13	R
Heligan	[8]		10	S
Pearl	[5]		8	S
Siberia	[5]		8	R
Pastoral	[7]		8	S
Jackpot	[7]		8	S
Muscat	[6]		8	S
Opal	[5]		8	S
Vertige	[8]		8	R
Sumo	[6]		8	S
Regina	[7]		8	S
Jewel	[6]		5	S
CI 9518		10	15	S
Tenn.61-119		11	8	R
Code 65		12	5	R

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

Table 3 *Reactions of spring barley cultivars, adult plants and seedlings to a mixture of net blotch isolates in glasshouse tests

Cultivar	Differential Code number	Adult plant reaction	Seedling reaction
Cellar		60	S
Otira		60	S
Tavern		50	S
Neruda		50	S
Annabel		50	S
Saloon		38	S
Pewter		35	S
Chime		30	S
Brise		30	S
Berwick		30	S
Prestige		20	S
Decanter		15	S
County		5	R
CI 5401	1	10	R
CI 6311	2	5	R
CI 9820	3	3	R
CI 739	4	5	S
CI 1243	5	5	R
CI 4795	6	2	R
CI 4502	7	3	R
CI 4979	8	10	S
Proctor	9	15	S
CI 9214	13	2	R

Adult plants assessed on % flag leaf area infected, mean of 2 plants
Seedlings assessed on reaction type on a 0-4 scale
Resistant = 0-2 (R), Susceptible = 3-4 (S)

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

M J ADAMS and C R COLLIER

IACR-Rothamsted, Harpenden, Hertfordshire AL5 2JQ

32 infected samples were received in 2000 of which 20 contained BaYMV and 15 had BaMMV. One new outbreak of resistance-breaking BaYMV was reported from Oxfordshire (cv. Epic). A sample of spring barley from Lincolnshire received in early July from a crop sown in late March proved to have BaMMV, the first time that symptoms and virus have been found on a spring cultivar sown in the spring.

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

RESULTS AND DISCUSSION

32 positive samples were received in 2000 of which 20 samples (62%) contained BaYMV and 15 (47%) had BaMMV (Table 1). There were insufficient data to make any sensible analysis of cultivar differences but there were two features of note. One new outbreak of resistance-breaking BaYMV was reported from Oxfordshire (cv. Epic) in an area with a long history of mosaic virus. The detection of BaMMV on cv. Optic from Lincolnshire is the first time that symptoms and virus have been found on a spring cultivar sown in the spring. The sample was received in early July from a crop sown in late March. It has long been assumed that the spring barley escapes infection but this result shows that this is not necessarily the case, although it is clearly a rare event.

Table 1 Mosaic virus samples from 2000, classified by cultivar

Cultivar	BaMMV alone	BaYMV alone	Both viruses	Total samples
Epic [R]	0	1	0	1
Flute	1	0	0	1
Halcyon	1	0	0	1
Heligan	0	1	0	1
Optic	1	0	0	1
Pastoral	1	0	0	1
Pearl	2	2	1	5
Plaisant	1	0	0	1
Puffin	1	0	0	1
Regina	2	12	1	15
Rifle	0	0	1	1
Spice	1	0	0	1
Vertige	0	1	0	1
Unknown	1	0	0	1
TOTAL	12	17	3	32

[R], resistant cultivar carrying the *rym4* gene

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

The incidence of oat mildew was generally very low in 2000, particularly on the winter crop. This was reflected in only three samples being received (Table 1) from which isolates of *Blumeria graminis* DC Speer f. sp. *avenae* were cultured and tested on seedlings of the differential cultivars (Table 2).

Table 1 Geographic and cultivar origins of oat mildew samples received in 2000

Location (county)	Cultivar
Ceredigion	Winter oat, Dula
Cambs	Dula

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.

CROWN RUST OF OATS

E R L JONES

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

Race 251 was again the predominant race. Virulence, to cvs Millennium and Viscount, which appear to carry a resistance in common, first identified in 1999, was identified in eleven isolates. The previously highly resistant spring oat Sailor was susceptible to one isolate, identified as race 265.

GLASSHOUSE SEEDLING TESTS WITH YEAR 2000 ISOLATES

Of the oat crown rust samples received in year 2000, thirteen were from spring and eight from winter oat cultivars. The geographic origins of the samples are given in Table 1.

Table 1 Geographic origins (county) of 2000 oat crown rust samples

Location	No. of samples
North Yorks	10
Ceredigion	5
Wilts	2
Cornwall	2
Unknown	2

All isolates were tested on the standard set of ten differential cultivars as well as on the winter oat cvs Millennium, Viscount and Sailor. Millennium and Viscount were included because one isolate from 1999 tests proved virulent on these cultivars. The spring oat Sailor was included because it has consistently shown high levels of resistance in previous tests. Plants were grown in a spore-proof glasshouse to expansion of the second-formed leaf when they were inoculated with one of the isolates, incubated for 16h in a dew simulation chamber at 15^{0}C in darkness, and transferred to the glasshouse for 14 days further incubation. Disease was assessed according to infection type using a standard 0-4 scale where 0-2 = resistant (R) and 3-4 = susceptible (S).

Results

Based on the responses of the differential cultivars, isolates were assigned race numbers from the International Register of Pathogenic Races of *Puccinia coronata* (Table 2).

Table 2 Races identified from 2000 isolates

Race	Susceptible differential cultivars	No. of isolates
251	Appler, Bond, Saia	15
289	Appler, Saia	2
236	Anthony, Appler, Saia	1
275	Appler, Bond, Ukraine, Saia	1
265	Appler, Bond, Landhafer, Trispernia, Saia	1

Seventy five percent of the isolates were identified as Race 251, which has been the most frequently identified race in recent seasons. Virulence to cvs Millennium and Viscount was identified in 11 isolates. Eight of these were identified as members of race 251 whilst one isolate each of races 289, 236 and 265 also carried virulence to these two winter oats. Race 265, has remained for many years at very low frequency in the pathogen population. However, the isolate collected in year 2000 was also virulent on cv. Sailor. This spring oat has previously shown high levels of overall resistance, both in NIAB trials (disease rating of 9 in 2000 NIAB Recommended List of spring oats) and in glasshouse tests at IGER. Although Sailor is now outmoded, the survey indicates that its resistance was losing effectiveness and this raises questions as to its value.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 2001

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 1999 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 THE SPREAD OF YELLOW RUST IN WHEAT, 2001

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

Choosing varieties to grow together

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

DG1
(*)
Buster
Charger
Claire
Consort
Deben
Option
Malacca
Soissons
Ashby (S)
Axona (S)
Chablis (S)
Imp (S)
Paragon (S)
Shiraz (S)
Wallace (S)

DG2
(WYR9, WYR6,9)
Rialto
Tanker

DG3
(WYR13)
Riband

DG7
(WYR CV)
Hereward
Shamrock

DG9
(WYR17)
Biscay
Buchan
Reaper
Savannah

DG10
(WYR6,17)
Equinox
Genghis
Madrigal
Napier

DG11
(WYR?)
Oxbow

(S) = *spring wheat*

	Companion DG						
Chosen DG	**1**	**2**	**3**	**7**	**9**	**10**	**11**
1	+	+	+	+	+	+	+
2	+	**Y**	y	+	y	**Y**	y
3	+	y	**Y**	y	y	y	y
7	+	+	y	**Y**	+	+	y
9	+	y	y	+	**Y**	**Y**	y
10	+	**Y**	y	+	**Y**	**Y**	y
11	+	y	y	y	y	y	**Y**

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