UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

Chairman:	Dr R Johnson
Secretary:	Dr R A Bayles National Institute of Agricultural Botany Huntingdon Road Cambridge CB3 0LE, UK (Tel: 44 (0)1223 276381)

1999 Annual Report

Editor: J D S Clarkson

Published by

The United Kingdom Cereal Pathogen Virulence Survey Committee

Cambridge, England

May 2000

Price £17-50

Printed by the National Institute of Agricultural Botany
Cambridge

MEMBERS OF THE UK CEREAL PATHOGEN VIRULENCE SURVEY COMMITTEE, 1999-2000

Dr M J Adams	IACR-Rothamsted, Harpenden
Dr R A Bayles	National Institute of Agricultural Botany, 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	National Institute of Agricultural Botany, Cambridge
Mr D Feuerhelm	British Society of Plant Breeders
Dr N V Hardwick	Central Science Laboratory, York
Mr G J Hilton	National Institute of Agricultural Botany, 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	National Institute of Agricultural Botany, Cambridge
Mr P L Stigwood	National Institute of Agricultural Botany, Cambridge
Dr J B Sweet	National Institute of Agricultural Botany, Cambridge

CONTENTS

	Page
THE UK CEREAL PATHOGEN VIRULENCE SURVEY	**1**
EXPLANATION OF TERMS	**3**
OCTAL NOTATION	**4**
SUMMARY OF RESULTS FOR 1999	**5**
WINTER CEREAL DISEASE SURVEYS, 1999 N V Hardwick, J E Slough and D R Jones	**8**
MILDEW OF WHEAT J D S Clarkson and S E Slater	**22**
YELLOW RUST OF WHEAT R A Bayles and P L Stigwood	**29**
BROWN RUST OF WHEAT E R L Jones	**37**
BROWN RUST OF WHEAT: NIAB ADULT PLANT TESTS J D S Clarkson and S J Mann	**45**
MILDEW OF BARLEY S E Slater and J D S Clarkson	**48**
MILDEW OF BARLEY IN NORTHERN IRELAND P C Mercer and A Ruddock	**57**
YELLOW RUST OF BARLEY G J Hilton and W C Hutton	**58**
BROWN RUST OF BARLEY E R L Jones	**61**
RHYNCHOSPORIUM OF BARLEY E R L Jones and A C Newton	**69**
NET BLOTCH OF BARLEY E R L Jones	**78**
FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY M J Adams and C R Collier	**83**
MILDEW OF OATS E R L Jones	**85**
CROWN RUST OF OATS E R L Jones	**89**
VARIETY DIVERSIFICATION SCHEMES FOR 2000	**93**

THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

OBJECTIVES

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

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

METHODS

The Survey is carried out annually. In April, a list of cereal cultivars from which disease samples are requested is sent to about 100 pathologists and agronomists throughout the United Kingdom, who collect samples of infected leaves from field crops and cultivar trials and send them to the two testing centres:

- National Institute of Agricultural Botany, Cambridge - for mildew and yellow rust of wheat and barley.
- Institute of Grassland and Environmental Research, Aberystwyth - for brown rust of wheat and barley, rhynchosporium and net blotch of barley, 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 resistances. The results of the virulence tests and the diversification schemes are published in the Annual Report.

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

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

REFERENCES

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

EXPLANATION OF TERMS USED TO DESCRIBE RESISTANCE AND VIRULENCE

SPECIFIC RESISTANCE AND SPECIFIC VIRULENCE

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

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

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

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

TERMS DESCRIBING RESISTANCE AT DIFFERENT GROWTH STAGES

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

- overall resistances -
  are effective at **all** growth stages.

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

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

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 '99: SUMMARY of PAPERS

• WINTER CEREAL DISEASE SURVEYS, 1999

A total of 420 randomly selected fields of winter barley and 432 fields of winter wheat were sampled as part of the 1999 national survey of cereal disease; nearly all fields had received fungicide treatment.

Of the barley diseases, leaf blotch was the most severe disease at 3.8% area of leaf 2 affected. Although not as severe as 1998, it was still the second highest level recorded since 1983 (6.5% area of leaf 2). Brown rust severity at 1.9% area of leaf 2 was again lower than 1998 but higher than in any survey since 1993. Net blotch levels were at their lowest since 1995, affecting 1.5% area of leaf 2 compared with 3.2% in 1998. Mildew was recorded more frequently than in 1998 and affected 1.0% of leaf 2 compared with 0.8% recorded in the previous survey. Yellow rust, septoria and *Selenophoma donacis* were recorded at trace levels. Moderate and severe levels of eyespot were the highest recorded since 1994.

Of the winter wheat diseases, *S. tritici* was the most severe foliar disease for the ninth consecutive year, affecting 6.7% of the area of leaf 2, the second highest level recorded since 1985, compared with 7.7% in 1998, 3.1% in 1997 and 2.1% in 1996. *S. tritici* was also present at trace levels on the ears. *S. nodorum* was present at 0.1% area of the second leaf affected but only at trace levels on leaf 1 and the ears. Brown rust affected 0.7% of the area of leaf 2 and for the second consecutive year was the highest level recorded since 1993. Mildew affected 0.2% of the area of leaf 2, twice as much as in 1998 which was the lowest level since the survey began in 1970, a similar figure to 1997. Yellow rust was recorded at trace levels on both leaves and on the ears. Moderate plus severe levels of eyespot were lower than 1998 but were the sixth highest 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 low in 1999, due to unfavourable spring/summer infection conditions, and fewer samples were processed. Virulence for Pm2, Pm4b, Pm6 and Pm8 is at very high frequencies in the population, corresponding to large areas of cultivars carrying these genes. The mildew population continues to be less diverse, with one dominant pathotype (V2,4b,5,6,8,Ta2) comprising 57% of the population; less complex pathotypes are decreasing in frequency. In general, the very limited range of specific resistance genes is not currently providing effective mildew control, although many cultivars possess good partial resistance. The new RL cultivar Napier has no effective specific resistance but is moderately resistant (rating 6). Shamrock may carry unknown effective specific resistance.

- **YELLOW RUST OF WHEAT**

Yellow rust was widespread in 1999 with 99% of isolates tested possessing virulence for WYR17. 1999 was the third consecutive epidemic year in major cereal growing areas. The virulence combination WYV6,17 was not detected in all regions, occurring mostly where the susceptible cultivar Madrigal (WYR6,9,17) was being widely grown. Virulence for Charger (NIAB yellow rust resistance rating 9) was detected in adult plant tests.

- **BROWN RUST OF WHEAT**

Several of the currently recommended and newly introduced winter and spring wheat cultivars showed high levels of resistance in field tests at IGER, Aberystwyth, and NIAB, Cambridge. Virulence to some previously resistant cultivars including Buchan, Genghis, Reaper and Claire was identified in one isolate (WBRS-99-10) in controlled climate tests but needs to be confirmed in the field. Increased virulence for the spring cultivar Chablis was detected.

- **MILDEW OF BARLEY**

Virulence frequencies were similar to previous years, with *Vra, Vg, V(CP), Va12* and *Va7* present at high levels in all populations. Frequencies of *Vh, Va7, VLa* and *V(Ab)* varied over the season, reflecting the presence of *Mla7* and *Mlh* in winter cultivars and *MlLa* and *Mla1* in spring cultivars. The trend towards more complex isolates continued and the diverse nature of the barley mildew population was sustained. The population was again capable of infecting the majority of cultivars in NIAB Recommended List trials. Only spring barley cultivars with *mlo* genes were mildew-resistant, although some isolates continued to give increased levels of infection on the *mlo* differentials Apex and Riviera in tests. No new resistances were identified, although Vanessa may carry new, unknown resistance. Due to the very low incidence of barley mildew in N. Ireland, no isolates were obtained.

- **YELLOW RUST OF BARLEY**

One sample of barley yellow rust was received in 1999, from a crop of the winter barley variety Regina, in East Yorkshire. The isolate obtained from the sample possessed the virulence BYV1,2,3. This virulence combination represents all the specific virulence factors in barley known to date. The crop concerned was showing over 3% infection on the flag leaf, and around 1% infection on leaf 2, at GS75. There is still a potential risk from this disease due to the large acreage of the susceptible cultivar Regina.

- **BROWN RUST OF BARLEY**

Glasshouse adult plant tests showed the majority of winter barleys to be susceptible to the prevalent pathotypes, although some appear to carry race specific resistances. Several spring barleys were resistant in the field and glasshouse to pathotypes carrying a range of virulences.

- **RHYNCHOSPORIUM OF BARLEY**

The race specific resistance BRR-2 is carried by many of the most widely grown winter barley cultivars. Very few of the most popular spring and winter cultivars carry resistance factors BRR-5, BRR-6 or BRR-8. Consequently virulences to these remain at a low frequency in the pathogen population. The winter cultivar Manitou was highly resistant in adult plant glasshouse tests whilst the spring barley cv. Chaser, thought to carry BRR-8, also expressed good resistance. Spring barleys grown in field nurseries at IGER and SCRI showed a range of quantitative responses with infection levels generally lower than those seen on corresponding cultivars in glasshouse tests.

- **NET BLOTCH OF BARLEY**

All of the 1999 samples were collected from cv. Regina, on which increased virulence was detected in some field crops in 1998 and confirmed in 1998 adult plant glasshouse tests. Several of the 1999 infected leaf samples were collected from commercial crops or trial plots with low levels of infection but some, from different locations, showed levels of disease higher than seen prior to 1998. The majority of the current NIAB Recommended winter and spring barleys were susceptible in glasshouse tests.

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

Only 24 infected samples were received in 1999, 3 of which contained barley mild mosaic virus (BaMMV) alone, 19 had barley yellow mosaic virus (BaYMV) alone and 2 contained both viruses. This is the smallest number of samples since the survey began in 1987 and provided insufficient data to analyse cultivar responses. No new outbreaks of resistance-breaking BaYMV were reported.

- **MILDEW OF OATS**

The widely virulent Race 7, which has remained at a low frequency over a number of years, was identified in two of the seven isolates tested. Cultivar Banquo expressed adult plant resistance, the remainder of the NIAB Recommended List winter and spring oat cultivars displaying a range of quantitative susceptible responses to the isolates. The resistance of the differential cultivar Cc 6490 (OMR-4) was effective, although it showed high levels of a resistant reaction to one isolate to which it had been susceptible in previous seedling tests.

- **CROWN RUST OF OATS**

The resistance of the spring oat cv. Sailor was effective in adult plant glasshouse tests but the previously highly resistant cvs Millenium and Viscount were overcome by race 221. This race has not previously been identified in the UK. The remainder of the currently recommended spring and winter oat cultivars were highly susceptible.

WINTER CEREAL DISEASE SURVEYS, 1999

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 420 randomly selected fields of winter barley and 432 fields of winter wheat were sampled as part of the 1999 national survey of cereal disease. Of the barley diseases, leaf blotch was the most severe disease at 3.8% area of leaf 2. Although not as severe as 1998 it was still the second highest level recorded since 1983 (6.5% average percent of leaf 2). Brown rust severity at 1.9% area of leaf 2 was again lower than 1998 but higher than in any survey since 1993. Net blotch levels were at their lowest levels since 1995 affecting 1.5% area of leaf 2 compared with 3.2% in 1998. Mildew was recorded more frequently than in 1998 and affected 1.0% of leaf 2 compared with 0.8% recorded in the previous survey. Yellow rust, septoria and *Selenophoma donacis* were recorded at trace levels. Moderate and severe levels of eyespot were the highest recorded since 1994. Of the winter wheat diseases, *S. tritici* was the most severe foliar disease for the ninth consecutive year, affecting 6.7% of the area of leaf 2, the second highest level recorded since 1985, compared with 7.7% in 1998, 3.1% in 1997 and 2.1% in 1996. *S. tritici* was also present at trace levels on the ears. *S. nodorum* was present at 0.1% of the area affected of the second leaf but only at trace levels on leaf 1 and the ears. Brown rust affected 0.7% of the area of leaf 2 and for the second consecutive year was the highest level recorded since 1993. Mildew affected 0.2% of the area of leaf 2, twice as much as in 1998 which was the lowest level since the survey began in 1970, a similar figure to 1997. Yellow rust was recorded at trace levels on both leaves and on the ears. Moderate plus severe levels of eyespot were lower than 1998 but were the sixth highest 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.*, 1998a, 1998b; Polley & Thomas, 1989; Polley *et al.*, 1993).

This summary report contains the results of the survey of foliar and stem base diseases of winter barley and winter wheat for the 1998-99 growing season, and includes information on fungicide use. The results are compared, where appropriate, with those from previous surveys (Hardwick *et al.*, 1998b, 1999).

METHODS

The 1999 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).

Regions 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 1998 MAFF agricultural census. The distribution of farms between regions was proportional to the regional area of winter barley and wheat grown and on the size of the arable area of the farms to be surveyed. There was an exception for Wales where additional addresses were requested in order to obtain sufficient sites for data comparison. A total of 420 randomly selected fields of winter barley and 432 fields of winter wheat were sampled. Calculation of the national results, based on a full stratification according to location and farm size resulted in utilisation of data from 340 and 350 samples of winter barley and winter wheat, respectively. A questionnaire giving agronomic details such as cultivar, sowing date and previous cropping as well as details of all pesticide applications was completed for each sample.

RESULTS

Winter barley

Severity of foliar and stem disease

Only one disease, leaf blotch reached levels of more than 2.0% area leaf 2 affected (Table 2). It was the most severe and the most widespread disease with 3.8% of leaf 2 affected, the second highest level since 1983 (Fig. 1), with a national occurrence of 81% of samples affected. Brown rust severity at 1.9% area of leaf 2 was the second most severe and common disease. Net blotch levels affected 1.5% area of leaf 2, a reduction of more than 50% from 1998. Mildew was recorded more frequently than in 1998 and affected 1.0% of leaf 2, the highest levels since 1996 (Fig. 1). Yellow rust, leaf spot and halo spot were all recorded at trace levels.

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

	Leaf 1	Leaf 2
Mildew	0.3	1.0
Brown rust	1.4	1.9
Net blotch	0.8	1.5
Leaf blotch	1.3	3.8
Leaf spot	tr	tr
Halo spot	tr	tr
Yellow rust	tr	tr
Insect damage	0.4	0.4
Green leaf area	85.6	68.7

tr = trace (< 0.05)

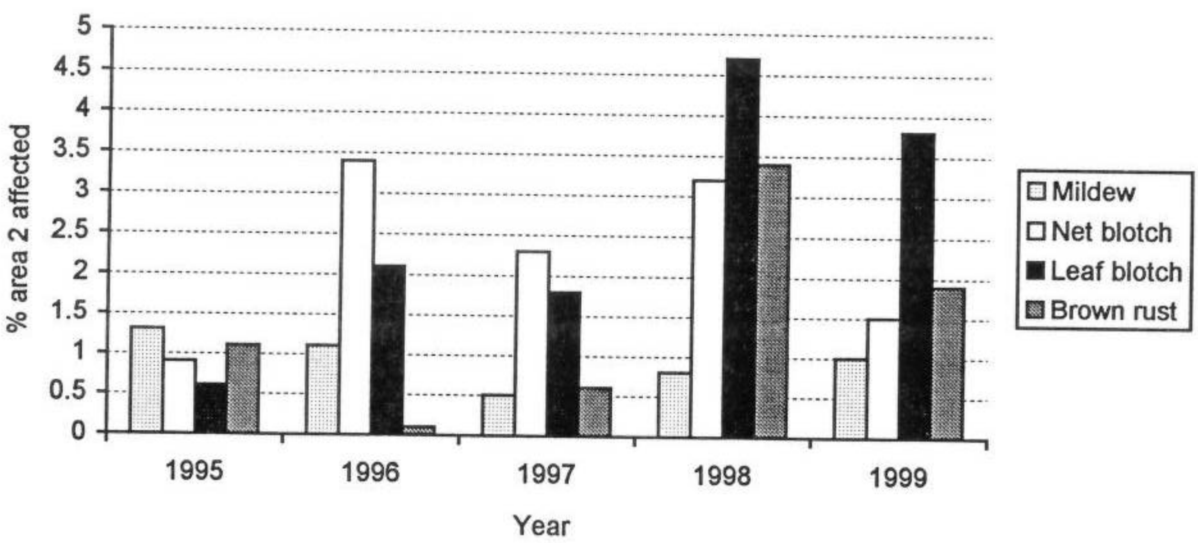

Fig 1 National foliar disease levels (mean % area leaf 2 affected)

Eyespot was recorded in 82% of crops, slightly fewer than in either 1997 or 1998, but was more severe, with 9.2% of stems affected by moderate and severe symptoms compared to 7.2% in 1998 and 9.1% in 1997. Sharp eyespot was recorded more frequently than in 1998, affecting 38% of crops sampled with moderate and severe symptoms affecting 1.6% of stems, slightly less than the 1.9% recorded in 1998. Fusarium symptoms were present in 88% of crops, with moderate and severe levels on 4.7% of stems compared with 10.5% of stems in 1998 (Table 3).

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

	Slight	Moderate	Severe
Eyespot	16.8	8.9	0.3
Sharp eyespot	2.6	1.5	0.1
Nodal fusarium	14.9	4.2	tr
Internodal fusarium	3.4	0.6	0.1
All fusarium	16.6	4.6	0.1

Regional disease severity

Levels of mildew were the highest since 1996, with the North East Region most severe. Net blotch was most severe in Wales and the West Midlands (3.1 and 2.8% area leaf 2 respectively). The incidence and severity of brown rust was highest in the East Midlands, 89.5% of samples were affected with an average percentage area on leaf 2 of 4.5%. Leaf blotch was most severe in the North West and South West and least severe in the Yorkshire and Humber Region (Table 4; Fig. 2). The highest incidence of halo spot occurred in Wales and the South West with 9.7% and 7.1% of samples affected. It was not recorded in the northern regions.

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	21	4.4	1.1	1.4	3.3	0.0	0.0	0.0
NW	14	1.1	2.0	0.7	8.8	tr	0.0	0.0
Y & H	64	1.2	0.9	0.9	1.8	tr	0.0	tr
EM	57	0.8	4.5	2.4	2.9	tr	0.0	0.0
WM	42	1.9	1.8	2.8	6.5	tr	tr	0.0
EAST	96	0.6	1.9	1.0	1.9	tr	tr	tr
SE	38	0.2	2.4	0.9	3.6	tr	tr	0.0
SW	56	0.6	1.2	1.0	7.4	0.1	tr	0.0
WALES	31	0.5	0.3	3.1	5.3	0.0	0.1	0.0
National (stratified)	340	1.0	1.9	1.5	3.8	tr	tr	tr

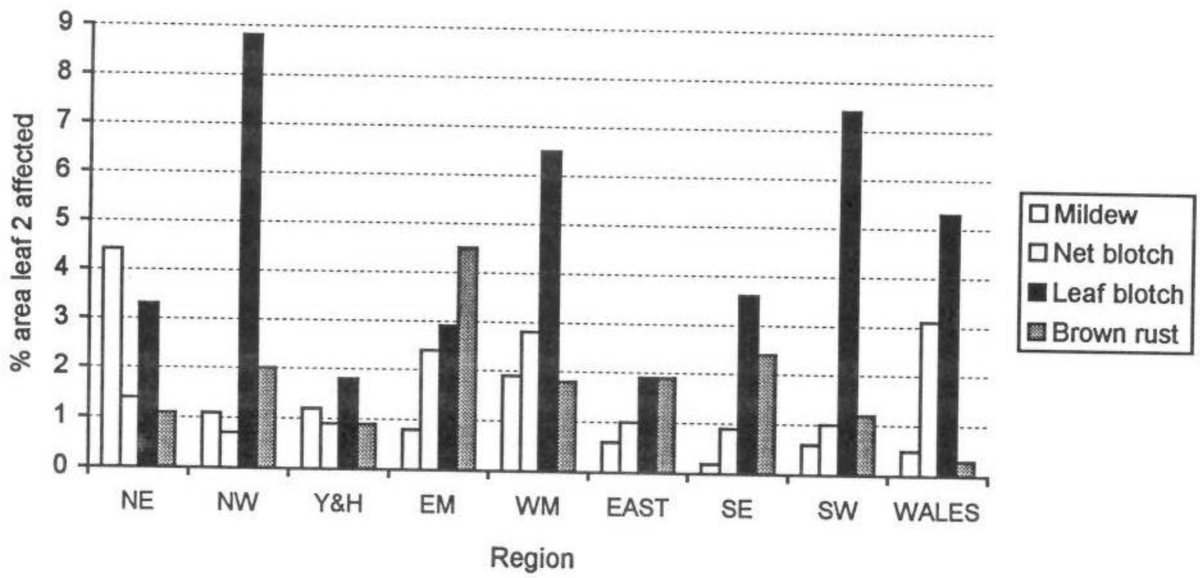

Fig 2 Regional foliar diseases levels (mean % area leaf 2)

The effect of cultivar on disease severity

Regina, Intro, and Fanfare were the three most popular cultivars grown, accounting for 34%, 13% and 11% of the national figure respectively. From the ten most popular cultivars in the stratified sample the highest level of leaf blotch was recorded on Pipkin at 14.9% of the area of leaf 2 (NIAB rating 4). For the third year brown rust was most severe on Hanna affecting 7.9% area of leaf 2 (NIAB rating 5). As in 1998, the highest net blotch levels were found on Muscat with 5.1% area of leaf 2 affected (NIAB rating 7) and again the highest mildew levels were recorded on Intro 2.1% area of leaf 2 (NIAB rating 6) (Fig. 3).

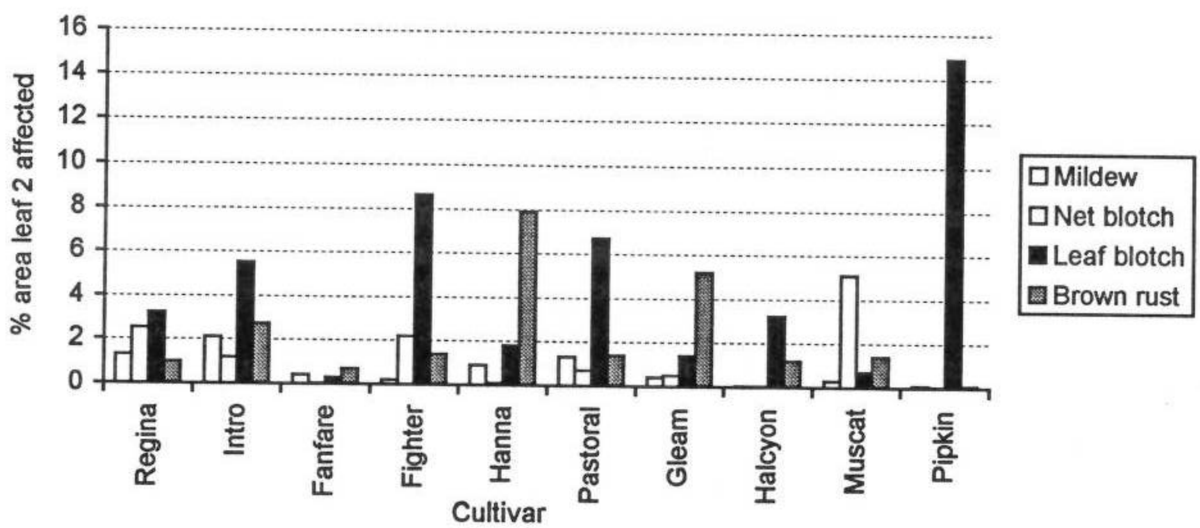

Fig 3 Foliar diseases on main cultivars (mean % area leaf 2)

Generally, foliar diseases appear to be more severe in crops drilled before 1 October and leaf blotch more severe on crops drilled before 24 September. Eyespot and sharp eyespot were more severe on crops drilled between 24 and 30 September and eyespot more damaging in crops following a cereal.

Fungicide sprays were used on 95% of crops with a mean of 1.6 sprays per crop. Five per cent of crops were treated with a fungicide before the end of tillering, 81% at or around GS 31 and 60% at or after flag leaf emergence. Forty one per cent of crops received a single spray, 73% at *c.* GS 31. Forty seven per cent were sprayed twice, with the majority (84%) at GS 31 with the second spray at or after GS 37. Seven per cent of crops received three or more fungicide sprays, a decrease of 4% when compared to the 1998 survey. The most commonly applied fungicide products were Amistar (191 applications), Unix (107 applications), Opus (86 applications) and Corbel (51 applications). The number of different foliar applied fungicide products totalled 87 with 25 active ingredients. Seventy five per cent of crops in the survey were grown from certified seed, and 88% of all crops were known to be grown from fungicide treated seed with 7% of growers unable to specify seed treatments.

Winter wheat

Severity of foliar and stem disease

Nationally, foliar disease levels were lower than in 1998 but were higher than for any other year since 1985. For the ninth consecutive year *Septoria tritici* (teleomorph: *Mycosphaerella graminicola*) was the most severe foliar disease, affecting 6.7% of the area of leaf 2, the second highest level recorded since 1985, compared with 7.7% in 1998, 3.1% in 1997 and 2.1% in 1996. *S. tritici* was also present at trace levels on the ears (Table 5). *Septoria nodorum* (teleomorph: *Stagonospora nodorum*) affected 0.1% of the area of the second leaf but only at trace levels on leaf 1 and the ears. Brown rust affected 0.7% of the area of leaf 2, which was the highest recorded level since 1993 (Fig. 4). Mildew affected 0.2% of the area of leaf 2, a figure similar to 1997 but with a reduced incidence. Yellow rust was recorded at trace levels on the leaves and ears. Fusarium ear blight symptoms were recorded in 33% of samples compared with 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	0.2	0.1
S. tritici	1.8	6.7	tr
S. nodorum	tr	0.1	tr
Yellow rust	tr	tr	tr
Brown rust	0.7	0.7	-
Didymella	tr	tr	-
Cephalosporium	tr	0.0	-
Tan spot	0.0	0.0	-
Insect damage	1.1	1.1	-
Green leaf area	89.9	79.0	-

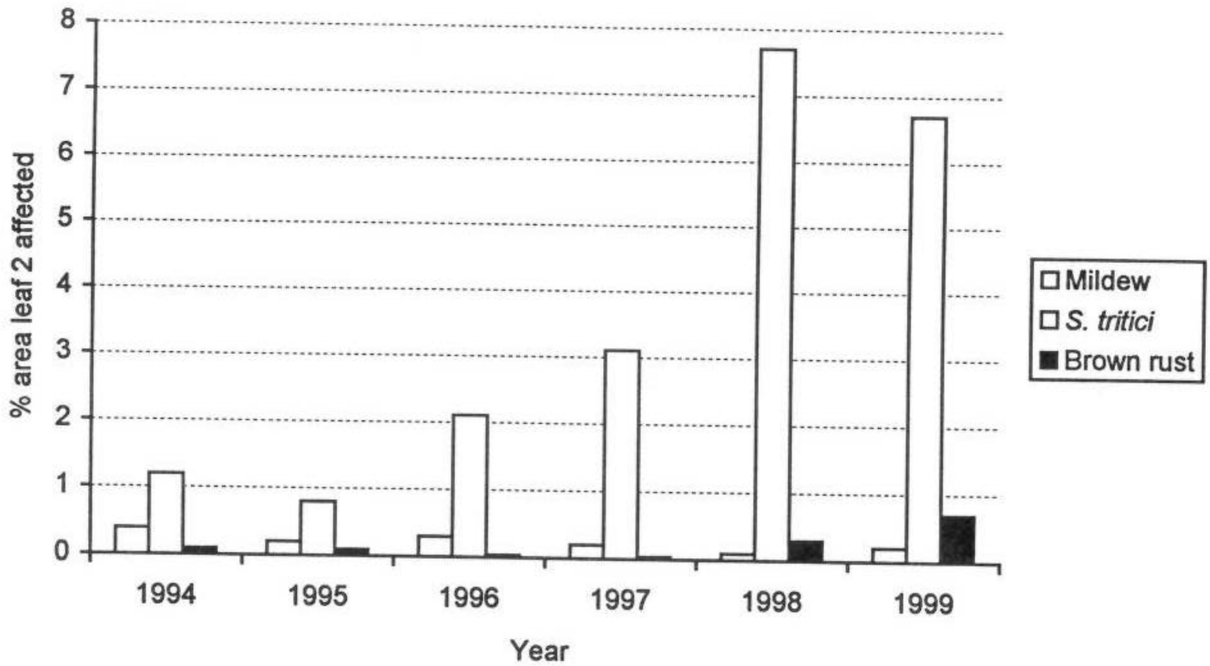

Fig 4 National foliar disease levels (mean % area leaf 2 affected), 1994-1999

Levels of eyespot, at 13.5% stems affected with moderate and severe symptoms, were lower than in 1998 (18.5%) (Fig 5). Moderate and severe symptoms of sharp eyespot affected 4.6% of stems and were the same as those recorded in 1998 (Fig. 6). The fusarium complex affected 20% of stem bases which was the lowest level for the 1990's although moderate plus severe levels were similar to 1998 (Table 6). Fusarium ear blight levels were lower than in 1998 but glume spot levels were slightly higher (Table 7).

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

	Slight	Moderate	Severe
Eyespot	16.4	12.7	0.8
Sharp eyespot	5.1	4.1	0.5
Nodal fusarium	11.1	3.1	tr
Internodal fusarium	5.8	2.2	tr
All fusarium	15.2	4.9	tr

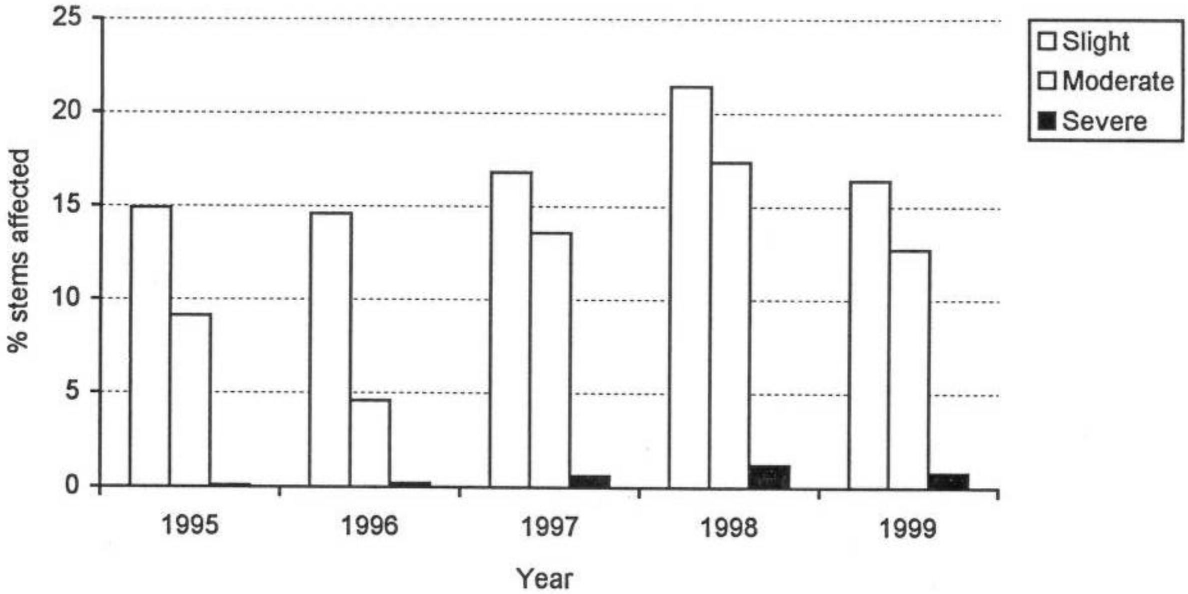

Fig 5 National levels of eyespot (mean % stems affected)

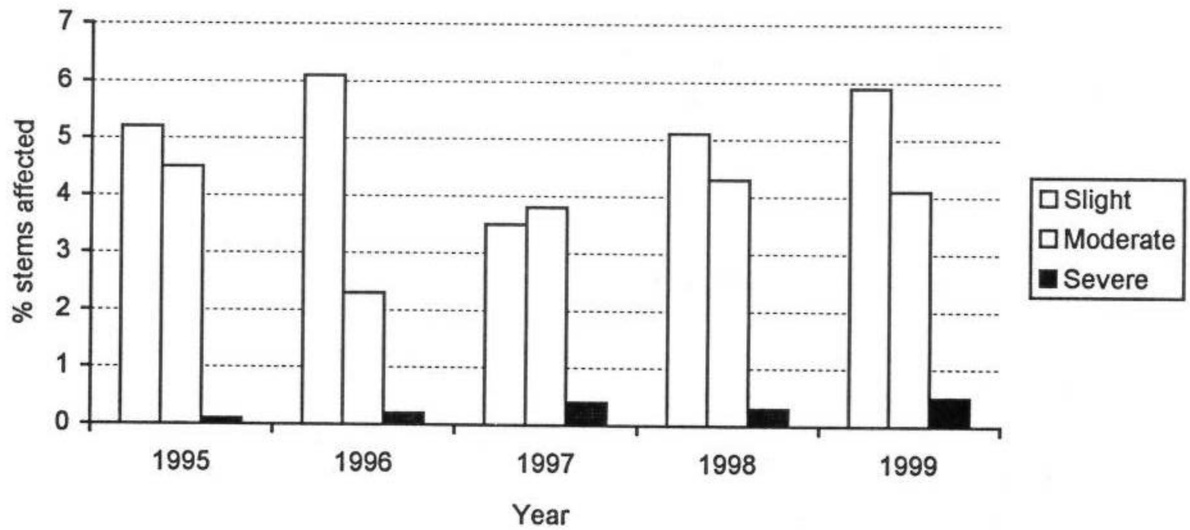

Fig 6 National levels of sharp eyespot (mean % stems affected)

Table 7 National fusarium levels on the ears

Year	% samples affected		% ears affected	
	Ear blight	Glume spot	Ear blight	Glume spot
1995	2.0	11.3	0.1	0.7
1996	1.9	10.6	0.1	0.7
1997	21.8	62.7	1.6	7.0
1998	61.2	41.0	12.1	3.3
1999	33.1	48.0	3.4	5.4

Take-all was present in 33% of crops. Take-all patches were recorded in 12.6% of crops compared with 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
	0	1	2	3	4	take-all
Number of crops (1998)	187.0	92.0	32.0	22.0	6.0	152.0
Per cent of total (1998)	55.2	27.1	9.4	6.5	1.8	44.8
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

* 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 18% of crops with the majority 78% recorded as category 1 (a scattering of plants showing symptoms). Of the remaining 22% with 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 *S. tritici* were found in the North West, Wales, West Midlands and the South West Regions and the lowest in the East. In the North East, East and South East the incidence of *S. tritici* was less than 90% while it was recorded in all samples received from the North West and Wales. The highest levels of brown rust were recorded in the East and none were recorded in the North East. The West Midlands had the highest levels of mildew with an average of 0.5% of leaf 2 affected (Fig. 7). Yellow rust was recorded at trace levels in all regions except the North East and North West where it was not found and in the South East and East where it was recorded at 0.1% of the area of leaf 2 affected. *S. nodorum* was recorded at less than 0.3% of leaf 2 in all regions apart from the Yorkshire and Humber Region (Table 9).

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

Region	No. of samples	Mildew	*Septoria tritici*	*Septoria nodorum*	Yellow rust	Brown rust	*Didy -mella*	Tan spot	*Cephalo -sporium*
NE	18	0.1	4.0	0.1	0.0	0.0	0.0	0.0	0.0
NW	8	0.1	18.3	0.1	0.0	0.1	0.0	0.0	0.0
Y&H	58	0.1	4.7	0.4	tr	0.4	tr	0.0	0.0
EM	78	tr	5.6	0.2	tr	0.2	tr	0.0	0.0
WM	38	0.5	13.3	0.2	tr	tr	tr	0.0	0.0
EAST	96	0.1	3.5	0.1	0.1	1.8	tr	0.0	0.0
SE	61	0.3	4.6	tr	0.1	0.1	tr	0.0	0.0
SW	45	0.3	11.2	0.1	tr	1.4	tr	0.0	0.0
WALES	30	0.1	17.2	0.1	tr	0.2	0.0	0.0	0.0
National (stratified)	350	0.2	6.7	0.1	tr	0.7	tr	0.0	0.0

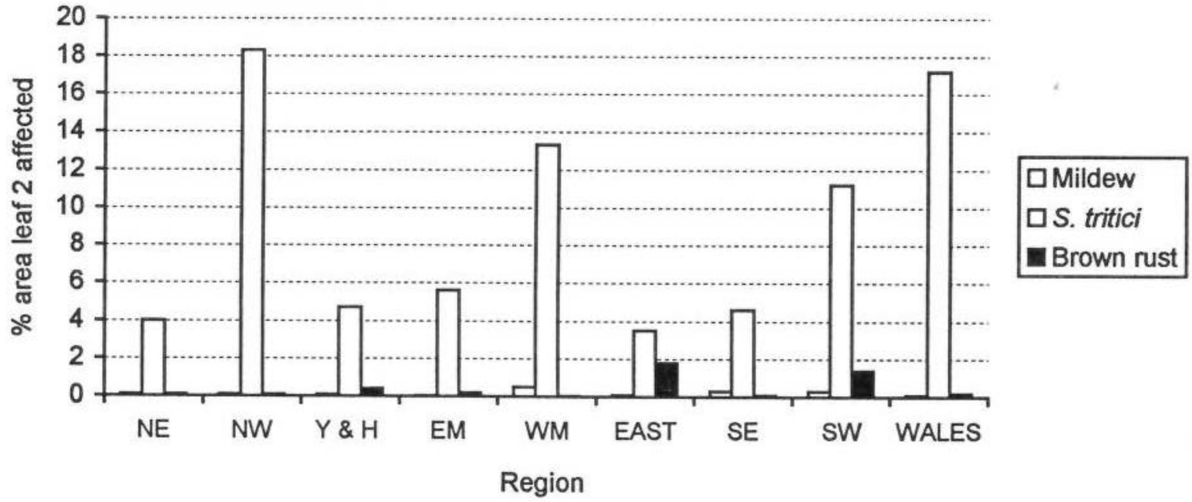

Fig 7 Regional foliar diseases levels (mean % area leaf 2)

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

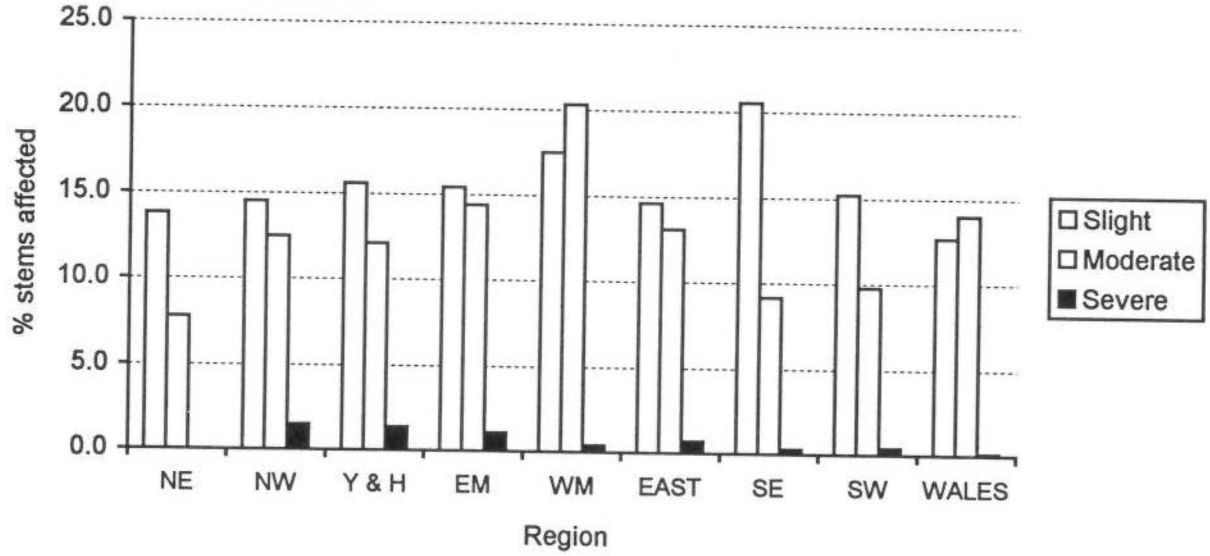

Fig 8 Regional eyespot levels (mean % stems affected)

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

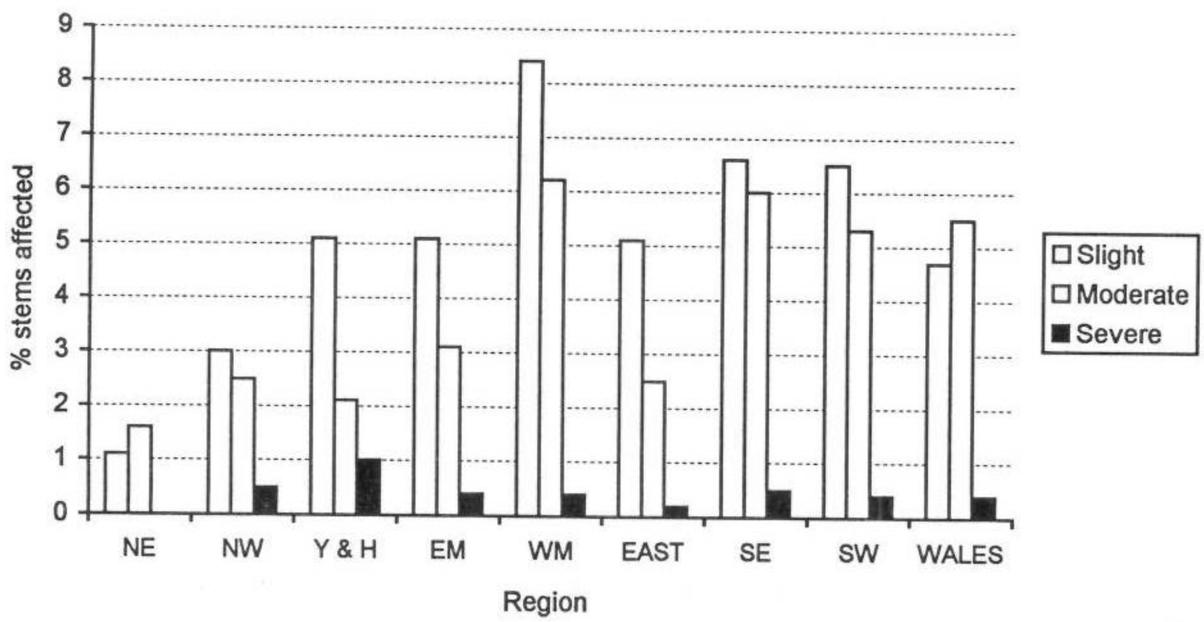

Fig 9 Regional levels of sharp eyespot (mean % stems affected)

Effect of cultivar on disease severity

After eight successive years Riband (11% of crops), was replaced by Consort (22% of crops) as the most commonly sampled cultivar in the survey. Equinox, a new cultivar to the survey last year, was third with 9% of crops. Riband showed the highest levels of *S. tritici*, with 10.0% area of leaf 2 affected (NIAB rating 3). Brown rust was more severe on Soissons, with 6.7% area of leaf 2 affected (NIAB rating 2). The most common of the new cultivars was Claire with 2% of the stratified survey (Fig. 10).

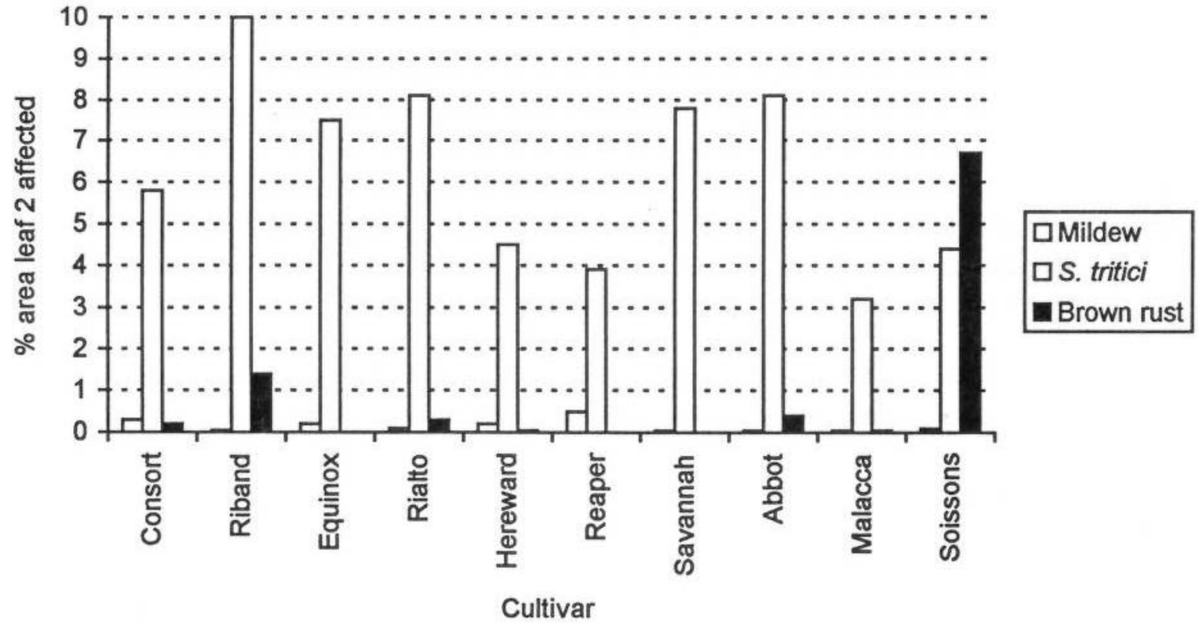

Fig 10 Foliar diseases on main cultivars (mean % area leaf 2)

As in past surveys the lowest levels of eyespot were found in crops following grass (3% of the stratified sample). Most crops followed a cereal or an oilseed rape crop (32% and 26% respectively). Sharp eyespot levels were most severe following another cereal but least severe after set-aside. Conversely, moderate and severe levels of fusarium stem base diseases were highest following set-aside. Take-all patches were recorded on more crops following wheat but fewer following oilseed rape. Monoculture had little effect on levels of either fusarium or sharp eyespot, but take-all and eyespot levels tended to be highest following one previous wheat crop. A non-cereal break of 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. *S. tritici* was most severe on crops drilled in late October and eyespot less severe in crops drilled after October.

Fungicide sprays were used on 99% of crops, with 89% receiving two or more treatments. The most popular regime, applied to 30% of crops, was a three-spray programme with the first spray aimed at GS 31, a second spray at GS 39 followed by a third aimed at GS 59. Thirty six per cent of crops received a two-spray programme. The most popular, applied to 20% of crops, was a first spray aimed at GS 31, followed by a second aimed at GS 39. Crops received on average 2.5 fungicide spray applications, the same as last year. Seventy per cent of crops were grown from certified seed with 93% of crops sown with fungicide treated seed with 3% of growers unable to specify seed treatments. Sixty two per cent of crops were treated with insecticides the majority (74%) received a single spray mostly in the autumn (58%).

DISCUSSION

Disease levels in 1999, although not as high as those in 1998 were nevertheless higher than average. Of particular concern is the trend of increasing levels of stem base diseases, particularly eyespot. This disease currently accounts for a third of the yield loss in wheat and 10% in barley. Sprays applied around GS 31 account for 81% of applications in winter barley and 84% on winter wheat. The increasing number of spray application at GS 31 on wheat are accounted for by early application of strobilurin-containing fungicides. Little attention is being paid to eyespot control, either in strategies using fungicides or cultivar resistance. Over 70% crops of winter wheat are sown with a NIAB rating of 5 and less.

Of the foliar diseases, *S. tritici* was the major disease in winter wheat with levels nine times higher than that of the next most evident disease, brown rust. The three dominant cultivars, Consort, Riband and Equinox all have NIAB resistance ratings of 5 or less for *S. tritici*. It is not surprising, therefore, that high disease levels were recorded despite increased fungicide application.

For the second year running the severity of rhynchosporium exceeded that of net blotch, reversing a trend that was established in 1995. Again the highest levels of net blotch were recorded on Muscat, belying its NIAB rating of 7. The highest levels of mildew were recorded on Intro, at twice the national average (NIAB rating of 6). Pipkin (NIAB rating 4) was the cultivar most severely affected by rhynchosporium at 14.9% area of leaf 2, nearly twice the level recorded on Fighter (NIAB rating 5).

With the increasing reliance being placed on fungicides for the control of foliar diseases of cereals, particularly *S. tritici* on winter wheat, it is not surprising that in seasons like 1998 and 1999, characterised by wet springs and early summers, disease control has been relatively poor.

ACKNOWLEDGEMENT

The project was funded by MAFF.

REFERENCES

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

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

Hardwick, N V, Slough J E & Jones, D R (1999). CSL/ADAS winter wheat and winter barley disease surveys, 1997. *UK Cereal Pathogen Virulence Survey 1998 Annual Report,* pp 7-19.

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

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

MILDEW OF WHEAT

J D S CLARKSON and S E SLATER

National Institute of Agricultural Botany, Huntingdon Road, Cambridge CB3 0LE, UK

Mildew levels were low in 1999, due to unfavourable spring/summer infection conditions, and fewer samples were collected. Virulence for Pm2, Pm4b, Pm6 and Pm8 is at very high frequencies in the population, corresponding to large areas of cultivars carrying these genes. The population continues to become even more homogeneous, with one dominant pathotype (V2,4b,5,6,8,Ta2) comprising 57% of the population. Less complex pathotypes are decreasing in frequency. Most current winter wheat cultivars are potentially susceptible to nearly all mildew isolates tested, but many have good partial resistance. The new RL cultivar Napier has no effective specific resistance but is moderately resistant (rating 6). Shamrock may carry effective, unknown specific resistance.

INTRODUCTION

Mildew levels were particularly low in winter wheat crops in 1999: winter infection was washed off by rain in the spring months and levels never recovered. Infection was also low in spring wheat. This greatly affected the number of samples collected, as the disease was difficult to find in most areas, except on the more susceptible cultivars.

METHODS

102 samples were collected from winter cultivars in 1999, the lowest number for over 15 years. Single colony isolates were successfully recovered from 81 samples and 148 were subsequently tested. The source cultivars of the tested isolates are shown below:

Winter cultivars	No. of isolates		No. of isolates		No. of isolates
Claire	9	Cantata	6	Napier	5
Buster	8	Charger	6	Savannah	5
Consort	8	Equinox	6	Cockpit	4
Eclipse	8	Genghis	6	Harrier	4
Rialto	8	Madrigal	6	Hussar	4
Shango	8	Malacca	6	Buchan	3
Soissons	8	Reaper	6	Aardvark	2
Hereward	7	Riband	6	Abbot	2
Spark	7				

The samples were collected from the following locations:

	No. of isolates
Headley Hall, N Yorks	69
Wye, Kent	42
NIAB HQ, Cambridge	28
Bridgets, Hampshire	9
Total	**148**

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 which are used to test for corresponding specific virulence genes/factors are shown in Table 1.

Table 1 Differential cultivars used to determine virulence factors in isolates of wheat mildew, 1999.

Differential cultivar	European code	Resistance genes
Cerco	none	None
Galahad	Pm2	*Pm2*
Chul	Pm3b	*Pm3b*
Armada	Pm4b	*Pm4b*
Flanders	pm5	*pm5*
Brimstone	Pm2, Pm6	*Pm2, Pm6*
Clement	Pm8	*Pm8*
Amigo	Pm17	*Pm17*
Maris Dove	Mld	*Mld*
Brock	Pm2, MlTa2	*Pm2*, Unknown
Mercia	Pm5, MlTa2	*Pm5*, Unknown
Tonic	MlTo	Unknown
Broom	MlBr	? *Pm3d*
Sicco	Pm5, MlSi2	*Pm5*, Unknown
Wembley	MlSo	Unknown
Axona	MlAx	Unknown
Soissons	MlSs*	Unknown
Aardvark	? Pm8, ? Mld	? Pm8, ? Mld
Shamrock	?	?

* tentative designation for specific resistance factor

RESULTS AND DISCUSSION

Virulence frequencies

Virulence for Pm2, Pm4b, Pm6 and Pm8 remains at very high levels in the wheat mildew population (Table 2). The majority of current cultivars select for these virulences: *eg* cultivars with the gene combination Pm2,Pm4b,Pm6 comprised 31% of the wheat area in 1999, while 21% was grown with Pm4b,Pm6,Pm8 cultivars.

Virulence for Pm5 and MlTa2 also occurred at high frequency. Although there is currently little selection for these virulences, they remain common in the population.

Table 2 Frequency of wheat mildew virulence factors, 1993-1999, and 1999 areas of cultivars with the corresponding resistance.

	Frequency of virulence factors (%)							% Area
Virulence factor	1993	1994	1995	1996	1997	1998	1999	1999*
2	98	99	99	100	100	100	100	53
3b	-	-	4	3	4	1	2	0
4b	79	84	88	93	98	100	99	48
5	95	92	92	93	95	88	91	<1
6	78	80	89	96	99	100	100	58
8	93	93	95	96	98	97	99	22
17	-	-	10	15	16	8	22	0
d	15	20	19	33	26	18	6	<1
2,Ta2	80	82	85	92	93	86	97	<1
To	18	24	18	29	29	16	16	<1
Br	20	27	21	32	30	16	15	1
5,Si2	39	26	22	32	21	17	20	0
So	22	21	10	15	15	10	6	0
Ax	10	14	11	24	20	7	1	<1
Soissons						65	57	2
Number of isolates tested	356	347	265	313	328	187	148	

* NIAB (1999)

The reduction in the number of isolates carrying Vd and VAx in 1999 may not reflect a true decrease in these virulences in the population, due to the non-random nature of the survey samples. 43 isolates from Cadenza (MlAx,Mld?) were tested in 1997, 5 in 1998 and none in 1999.

Virulence frequencies for MlTo, MlBr and MlSi2 remain similar to 1998 values (Clarkson & Slater, 1999). Very few cultivars carry these resistance factors: *eg* Spark (MlTo) represents less than 1% of the wheat area, while MlBr occurs only in some spring wheat cultivars. None of the current cultivars carry MlSi2. There is no obvious selection for VSo, which continues to decline in frequency.

Virulence for Pm3b again occurred at a low level in the population, although no current cultivars are known to carry this gene. Similarly, no cultivars carry Pm17 but the corresponding virulence continues to show an increase in frequency; this may be an artefact associated with the differential cultivar used. However, both these resistance genes are believed to be currently used by wheat breeders in the UK.

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 57% of the isolates tested (Table 3). Only 22 different pathotypes were identified in 1999, a further measure of the decreasing variability of the population (although sample numbers were lower in 1999). 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, 1993-1999, 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
2,4b,5,6,8	6	8	8	4	3	9	<1
2,4b,6,8,Ta2	1	2	3	1	2	6	5
2,4b,5,8,Ta2	4	4	2	1	<1	0	0
2,4b,5,6,8,Ta2	25	26	38	35	42	38	57
2,4b,5,6,8,Ta2,To,Br	4	5	6	4	7	5	9
2,4b,5,6,8,Ta2,Si2	0	2	4	6	4	5	11
2,4b,5,6,8,Ta2,Si2,So	8	6	8	4	7	4	2
2,4b,5,6,8,d,Ta2	2	7	5	5	3	6	2
2,4b,5,6,8,d,Ta2,To,Br Ax	2	3	3	6	10	1	<1
2,4b,5,6,8,d,Ta2,To,Br Si2,So,Ax	1	2	<1	5	3	0	0
Number of pathotypes	78	71	57	59	44	35	22
Number of isolates	356	347	265	313	328	187	148

Complexity of isolates

There is little change in the complexity of the wheat mildew population. The majority of isolates tested in 1999 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, 1997-1999.

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

* 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 98% of mildew isolates (Table 5). However, most of the commonly grown cultivars exhibit moderate levels of non-specific resistance. Savannah shows the highest level of non-specific resistance, with a resistance rating of 8, although its specific resistance factors are matched by 98% of the population.

The new RL variety Napier possesses no useful specific resistance but is moderately resistant (rating 6) to mildew. Shamrock appears to have an effective unknown specific resistance, although virulence to this was detected in a few isolates in 1998 (Clarkson & Slater, 1999).

Table 5 Proportion of mildew isolates able to infect winter wheat cultivars in Recommended List trials (2000 Recommended List cultivars in **bold**, mildew resistance ratings in brackets).

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Buster (4)	100	Genghis (6)	99
Charger (7)	100	**Madrigal (6)**	99
Eclipse (7)	100	**Malacca (7)**	99
Hereward (6)	100	**Riband (6)**	99
Reaper (6)	100	**Buchan (6)**	98
Rialto (6)	100	**Napier (6)**	98
Claire (4)	99	**Savannah (8)**	98
Cockpit (6)	99	**Soissons (8)**	57
Consort (6)	99	**Shamrock (8)**	0
Equinox (5)	99		

Resistance factors in new cultivars

Further tests in 1999 suggested that Equinox carries Pm2, in addition to Pm6 and Pm8 (Table 6). Identification of Pm2 in new cultivars is difficult, due to the absence of isolates with V4b,V6, V7 but lacking V2. All but one of the isolates with virulence for Aardvark tested in 1998 and 1999 also carried Vd, suggesting that this cultivar carries Mld, possibly inherited from its parent Cadenza, in addition to Pm8. As all isolates with virulence for Cadenza also carry Vd, it seems probable that Cadenza carries Mld.

Table 6 Specific mildew resistance factors in winter wheat cultivars (2000 Recommended List cultivars in **bold**)

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

REFERENCES

Clarkson, J D S & Slater, S E (1999). Mildew of Wheat. *UK Cereal Pathogen Virulence Survey 1998 Annual Report,* pp 20-26.

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 (1999). Seed Production No. 22, November 1999.

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

YELLOW RUST OF WHEAT

P L STIGWOOD and R A BAYLES

National Institute of Agricultural Botany, Huntingdon Road, Cambridge CB3 0LE, UK

Yellow rust was widespread in 1999 with 99% of isolates tested possessing virulence for WYR17. 1999 was the third consecutive epidemic year in major cereal growing areas. The virulence combination WYV6,17 was not detected in all regions, occurring mostly where the susceptible cultivar Madrigal (WYR6,9,17) was being widely grown. Virulence for Charger (NIAB yellow rust resistance rating 9) was detected in adult plant tests.

1999 VIRULENCE SURVEY

The resistant cultivar Consort (NIAB yellow rust resistance rating 9) became the most widely grown variety in 1999. Cultivars possessing WYR17 decreased from 24% in 1998 to 14% in 1999. Cultivars possessing the combination of WYR6 with WYR17 increased from 5% to 11% of the total acreage in 1999.

Table 1 Popularity of winter wheat cultivars, 1999
(from seed certification statistics for England and Wales)

Cultivar	WYR Factors	NIAB Resistance Rating (1-9)	% acreage
Consort	CV	9	23.8
Riband	13	6	12.4
Rialto	6,9	5	9.4
Hereward	CV	7	7.9
Equinox	6,9,17	5	7.7
Charger	? 6 + APR	9	4.8
Savannah	9,17	5	4.1
Abbot	17	5	4.0
Malacca	?17 + APR	9	3.8
Reaper	17	4	3.5
Madrigal	6,9,17	3	3.2
Soissons	3	7	2.8
Brigadier	9,17	1	1.4
Hussar	9,17	4	1.3
Claire	Rx + APR	9	1.3

Table 2 1999 isolates - cultivars of origin

Variety	WYR factors	% isolates
Savannah	9,17	15.5
Equinox	6,9,17	10.3
Cockpit	17	7.2
Riband	13	6.2
Claire	R	6.2
Madrigal	6,9,17	5.2
Hussar	9,17	4.1
Napier	6,9,17	4.1
Eclipse	6,17	4.1
Consort?	R	3.1
Brigadier	9,17	3.1
Buchan	9,17	3.1
Malacca?	?17+APR	2.1
Genghis	6,9,17	2.1
Reaper	17	2.1
Shango	6	1.0
Charger	?6+APR	1.0
Cantata	17	1.0
Shamrock	CV	1.0
Axona	R	1.0
Hereward	CV	1.0
Spark	CV	1.0
Harrier	9,17	1.0
Rialto	6,9	1.0
12 others		12.3

97 isolates of *Puccinia striiformis* were tested in seedling virulence tests. These were obtained from 36 different cultivars (Table 2), mainly of the WYR17 type. Isolates received from WYR6,17 and WYR6,9,17 cultivars, Napier, Madrigal, Equinox, Genghis and Eclipse, accounted for 26% of the total received, a large increase on the previous year. Isolates were received from most regions of the UK including Scotland.

Table 3 Differential cultivars used in seedling virulence tests in 1999
(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 6	Yr6, Yr 2
Lee	WYR 7	Yr 7
Reichersberg 42	*WYR 7*	*Yr 7 +*
Compair	WYR 8	Yr 8
Kavkaz x 4 Federation	WYR 9	Yr 9
Moro	*WYR10*	*Yr 10*
*Yr15/6*AvS*	*WYR15*	*Yr 15*
VPM 1	WYR17	Yr 17
Carstens V		CV
Avocet 'R'		Yr A +
Suwon 92 x Omar		So
Strubes Dickkopf		Sd
Spaldings Prolific		Sp
Additional set		
Madrigal	WYR 6,9,17	Yr6+Yr9+Yr17
Parade	WYR R	

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

Table 4 Virulence factor frequency % (from natural infection)

Virulence Factor	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99
WYV 1	76	78	87	68	62	85	91	88	89	65	90	97	100	99	99
WYV 2	100	100	100	100	100	100	100	100	98	100	99	97	100	99	99
WYV 3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 4	45	70	47	78	97	91	86	86	89	86	67	59	47	79	87
WYV 6	90	96	89	72	57	69	64	88	68	41	35	16	1	7	21
WYV 7	3	22	8	6	2	9	19	7	8	4	0	3	7	4	10
WYV 8	*	*	*	*	*	*	0	0	0	0	0	0	0	0	0
WYV 9	3	4	5	66	99	94	88	76	84	94	95	97	99	99	99
WYV17											57	84	99	99	100
CV										75	55	9	13	1	4
YrA+														84	91
So														78	91
Sd														100	98
Sp														0	0
Parade									3	0	0	0	0	0	0
Madrigal												0	1	6	19
No. of isolates	29	23	52	71	156	67	42	77	63	49	83	32	138	94	97

Seedling virulence frequencies are given in Table 4. The frequencies of WYV1, WYV2, WYV3, WYV9 and WYV17 remained at, or close to, 100%. The frequency of WYV4 increased slightly. WYV6 increased significantly, reflecting the increase in acreage of WYR6,17 and WYR6,9,17 cultivars in 1999. WYV7 increased slightly to 10%, although with no WYR7 cultivars currently being grown this is probably of no significance.

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

Virulence for Madrigal (WYR 6,9,17) increased threefold in 1999, compared with 1998.

Table 5 Pathotype frequencies (%) in 1998 and 1999

	% frequency	
Pathotype	**1998**	**1999**
WYV1,2,3,9,17	17	10
WYV1,2,3,4,9,17	72	57
WYV1,2,3,6,9,17	3	2
WYV1,2,3,4,6,9,17	2	16
WYV1,2,3,4,7,9,17	4	9
WYV1,2,3,4,6,7,9,17	1	2
WYV1,2,3,4,9,17,CV	0	2
WYV1,2,3,4,7,9,17,CV	0	1
WYV3,4,6,CV,17	1	1

Pathotype frequencies are given in Table 5.

Disregarding virulence for the new differentials YrA+, So, Sd and Sp, the most common pathotypes were WYV1,2,3,4,9,17 (57% compared to 72% in 1998), WYV1,2,3,4,6,9,17, first identified in 1998,(16% compared to 2% in 1998), WYV1,2,3,9,17 (10% compared to 17% in 1998) and WYV1,2,3,4,7,9,17 (9% compared with 4% in 1998).

The pathotype WYV1,2,3,4,6,7,9,17, first identified in 1998, was again found in 1999 (2% of isolates).

Two new pathotypes were identified in seedling tests, WYV1,2,3,4,9,17,CV, and WYV1,2,3,4,7,9,17,CV. Identification of these awaits confirmation in adult plant polythene tunnel tests, in 2000. The Carstens V virulence is sometimes difficult to detect at the seedling stage as the expression of the Carstens V resistance is sensitive to environmental conditions, and thus requires confirmation at adult plant stage.

ADULT PLANT TESTS

10 isolates from the 1998 survey (Table 6) were tested for virulence on adult plants of 30 cultivars in polythene tunnels and on seedlings of the same cultivars. The isolates were chosen on the basis of their seedling virulence phenotypes and the cultivars from which they had been collected.

Table 6 Isolates of *Puccinia striiformis* used in adult plant tests

Isolate code	Source: Cultivar	Source: Location	WYV Factors
98/83	Savannah	Scotland	1,2,3,4,9,17
98/92	Claire	Cambridgshire	1,2,3,4,9,17
98/111	Brigadier	N. Ireland	1,2,3,4,9,17
98/49	Brigadier	Wales	1,2,3,4,7,9,17
98/64	Madrigal	Kent	2,3,4,6,9,17
98/86	Aardvark	Cambridgshire	1,2,3,6,9,17
98/106	Marshall	Cambridgshire	1,2,3,6,9,17
98/28	Madrigal	Lincolnshire	1,2,3,4,6,9,17
98/96	Madrigal	Lincolnshire	1,2,3,4,6,7,9,17
98/108	Shamrock	Lincolnshire	3,4,6,CV,17

Adult plant polythene tunnel tests are given in Table 7.

All ten isolates carried the WYV17 virulence, the range including virulence combinations WYV9,17, WYV7,9,17, WYV6,9,17, WYV6,7,9,17 and WYVCV,17.

Isolate 98/108 appeared to carry virulence for WYRCV and WYR17 at the seedling stage. However this was not confirmed at the adult plant stage. Cultivars possessing WYRCV were infected, but WYR17 cultivars only became infected late in the season due to contamination from adjacent tunnels containing WYV17. 98/108 infected Charger to a maximum of 10% (mean 5%). Virulence for Charger was seen in adult plant tests in 1994, but at much lower infection levels, and was not seen again until 1999. Because of this, Charger still has a resistance rating of 9.

Isolates containing WYV6,9,17 gave high infection levels on Madrigal. The other five WYR6,17 and WYR6,9,17 cultivars were less susceptible than Madrigal. They ranked in order of susceptiblity (most to least) as follows: Napier, Equinox, Genghis, Aardvark and Eclipse.

Cockpit (WYR17) proved to be very susceptible to all WYV17 isolates, but overall was slightly less susceptible than Brigadier. These two cultivars had similar infection levels early in the season, but Brigadier proved more susceptible at the end of the season.

Five cultivars with effective adult plant resistance (Malacca, Apostle, Buster, Consort and Claire), retained their complete field resistance to all ten isolates.

All isolates possessed WYV13 as exhibited by infection on Riband (WYR13).

Due to an error at sowing, Hobbit (WYR14) was not included in the adult plant polythene tunnel tests in 1999. WYV14 has been widespread in UK isolates for the last two years, and it is likely that this was the case in 1999.

REFERENCE

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

Table 7 Adult plant tests 1999. % leaf area infected with yellow rust (mean of 4 assessments).

	Isolate:	98/83	98/92	98/111	98/49	98/64	98/86	98/106	98/28	98/96	98/108
Cultivar	WYR	Virulence in seedling tests given in Table 6.									
Abbot	17	3	5	9	7	9	11	9	4	9	1
Cantata	17	3	7	7	2	5	13	9	5	7	2
Cockpit	17	23	30	21	30	25	38	22	34	24	8
Reaper	17	24	14	12	14	18	24	15	24	16	5
Brigadier	9,17	32	26	25	34	38	52	35	37	40	10
Buchan	9,17	22	19	22	23	25	25	22	28	29	5
Harrier	9,17	19	18	19	24	22	23	14	28	23	7
Hussar	9,17	15	10	12	12	18	13	9	16	12	4
Savannah	9,17	15	20	14	14	20	22	13	16	14	5
Aardvark	6,9,17	1	0	4	0	6	13	13	11	10	0
Genghis	6,9,17	0	2	7	3	19	15	13	15	14	3
Equinox	6,9,17	3	1	9	1	17	18	15	19	17	0
Madrigal	6,9,17	8	6	19	4	29	36	26	31	33	8
Napier	6,9,17	4	2	9	1	17	22	16	25	13	2
Eclipse	6,17	0	0	1	0	4	12	11	8	9	0
Shango	6	4	1	4	1	17	22	11	19	13	2
Rialto	6,9	3	3	10	2	14	16	17	16	17	1
Hereward	CV	0	0	0	0	0	0	0	0	0	9
Shamrock	CV	0	0	0	0	0	0	0	0	0	2
Spark	CV+	1	2	3	1	4	8	5	7	9	6
Malacca	?17+APR	0	0	0	0	0	0	0	0	0	0
Apostle	2,6+APR	0	0	0	0	0	0	0	0	0	0
Buster	R Par	0	0	0	0	0	0	0	0	0	0
Consort	R	0	0	0	0	0	0	0	0	0	0
Claire	Rx+APR	0	0	0	0	0	0	0	0	0	0
Charger	?6+APR	0	0	0	0	0	0	0	0	0	5
Soissons	0	2	3	6	2	2	4	6	5	4	1
Riband	13	5	11	7	6	11	15	14	13	11	5
Brock	7,14	0	0	0	0	0	0	0	0	0	0

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

BROWN RUST OF WHEAT

E R L JONES

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

Seedling and adult plant tests in controlled environments and field adult plant tests showed that several of the current NIAB Recommended List wheat varieties and newly introduced cultivars carry high levels of resistance. Virulence to some previously resistant cultivars was identified in one isolate (WBRS-99-10) in controlled climate tests but this needs to be confirmed in field conditions.

GLASSHOUSE SEEDLING TESTS WITH 1999 ISOLATES

The 1999 samples of brown rust were collected from one spring and twenty-two winter wheat cultivars and came from the following locations (Table 1).

Table 1 Geographic origins (county) of 1999 brown rust samples.

County	Number of isolates
Cambs	16
Lincs	1
Suffolk	2
Glos	2
Hants	1
Yorks	1

Isolates of *Puccinia recondita* were cultured from twenty-two of these and tested on a set of differential cultivars which comprised the standard WBR differential cultivars and cv. Thatcher backcross lines carrying different Lr resistance factors. Some newly-introduced winter wheats were also included in the tests as were some winter and spring wheat cultivars which have expressed high levels of resistance in previous years' tests (Table 2).

The standard differential cultivars 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.

Seedlings were grown and inoculated under standard conditions and, following incubation in dew simulation chambers at 15°C, 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).

Table 2 Cultivars used in tests with 1999 isolates

Standard differential cultivars (WBR-factor)	Thatcher Lr lines		Spring and winter cultivars
Clement (1)	1	15	Napier
Fundin (2)	2a	17	NCF 19606
Norman (2)	2b	19	Aardvark
Hobbit (2)	2c	20	Genghis
Sappo (3)	3	21	Abbot
Maris Halberd (4)	3bg	23	Madrigal
Sterna (7)	3ka	24	Reaper
Sabre (7)	9	26	Buchan
	11	28	Claire
	13	37	Chablis
	14a		Shiraz

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.

Based on the responses of the standard differential cultivars, all isolates carried two or fewer virulence factors (Table 3).

Table 3 Virulence combinations and their frequencies identified from the 1999 isolates

Virulence combinations	Frequency
WBV-1	0.18
WBV-2*	0.23
WBV-1,2	0.09
WBV-0	0.50

*Virulence to WBR-2 was based on the responses of cv. Fundin.
Adult plant tests may identify additional virulence factors in the isolates.

The frequencies of individual virulences to the Thatcher-Lr backcross lines and the standard differential cultivars are given in Table 4. The majority of the resistances, many of which are temperature-sensitive, conferred by the Thatcher-Lr lines were effective against the 1999 isolates whilst the resistances of some of the others were effective to the majority of the isolates. Of the lines to which there was a high virulence frequency, the resistances Lr13 and Lr37 are not expressed until later growth stages, although the former line was resistant to five isolates at 25°C. The resistance of Lr26 was overcome by seven isolates, cv. Clement (WBR-1) also being susceptible to these isolates only. The Lr3 group of lines, virulence to which has been identified at a low frequency in recent years, were resistant as were cvs Sterna (WBR-7) and Sabre (WBR-7) which, from previous years' tests, appear to carry the same resistance as these lines.

Table 4 Virulence frequencies corresponding to each Thatcher-Lr backcross line to 1999 isolates of *Puccinia recondita* at two temperatures, 10°C and 25°C.

Reaction Profile		Thatcher line (Lr gene)										
10°C	25°C		1	2a	2b	2c	3	3bg	3ka	9	11	13
R/MR	R/MR		1.00	0.87	0.65	0.52	0.57	0.57	0.78	0.91	0.13	-
R/MR	MS/S		-	-	-	-	-	-	-	-	0.34	-
MS/S	R/MR		-	0.13	0.13	0.22	0.43	0.43	0.22	0.09	0.04	0.22
MS/S	MS/S		-	-	0.22	0.26	-	-	-	-	0.49	0.78
		14a	15	17	19	20	21	23	24	26	28	37
R/MR	R/MR	-	0.87	-	1.0	0.32	1.0	-	1.0	0.68	0.95	-
R/MR	MS/S	-	0.13	-	-	0.68-	-	-	-	-	-	-
MS/S	R/MR	-	-	1.0	-	-	-	1.0	-	-	0.05	-
MS/S	MS/S	1.0	-	-	-		-	-	-	0.32	-	1.0
					Standard differential cultivars							
					Clement (WBR-1)	Fundin (WBR-2)	Norman (WBR-2)	Hobbit (WBR-2)	Sappo (WBR-3)	Halberd (WBR-4)	Sterna (WBR-7)	Sabre (WBR-7)
R/MR	R/MR				0.68	0.41	0.64	0.64	0.45	0.77	0.27	0.27
R/MR	MS/S				-	-	-	-	0.55	0.23	-	-
MS/S	R/MR				-	0.27	0.14	0.18	-	-	0.73	0.73
MS/S	MS/S				0.32	0.32	0.22	0.18	-	-	-	-

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

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

Of the current NIAB Recommended List and newly introduced wheat cultivars included in tests cvs Napier, Aardvark, Madrigal and Shiraz (WBR-7+) were resistant at both temperature regimes but the resistance of cv. Abbot was overcome by four isolates. Cultivars Buchan and Genghis were susceptible to the same two isolates but were resistant to the others at 10°C and 25°C. The temperature-sensitive resistances of cvs Chablis (WBR-7) and NFC 19606 were effective at the higher temperature whilst that of cv. Reaper, also more readily expressed at 25°C, was overcome by eight isolates. Cultivar Claire was susceptible to the 1999 isolates.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Winter and spring wheat cultivars, including those on the current NIAB Recommended List, the standard differential cultivars and cv. Thatcher backcross lines carrying different Lr resistance factors, were sown in each of two nurseries. The nurseries were inoculated with one or other of the following isolates of *P. recondita*.

WBRS-98-20 (*WBV-1,2,7)	ex cv. Chablis, Cambridge
WBRS-97-1 (WBV-0)	ex cv. Riband, Unknown

*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 disease built up on the susceptible cultivars with cv. Arina (susceptible check) becoming heavily infected (Table 5).

The reaction of cv. Huntsman (WBR-5) to the isolates indicate that they both carry WBV-5, identifiable only in adult plant tests. Isolate WBRS-97-1 infected cv. Fundin (WBR-2) although it was not identified as carrying the corresponding virulence WBV-2 in original seedling tests.

The majority of the current NIAB Recommended List and newly introduced wheat cultivars expressed high levels of adult plant or overall resistance although virulence compatible to some of them has been identified in field or controlled environment tests at IGER, Aberystwyth, or at NIAB, Cambridge. The spring wheat cultivars Samoa and Raffles, for example, expressed high levels of a resistant or mixed resistant reaction respectively to isolate WBRS-98-20 but were susceptible to a range of isolates in 1999 NIAB tests.

Of the Thatcher-Lr backcross lines, which comprised the standard set agreed among European leaf rust workers, the majority were susceptible (Table 6). The type of resistance, adult plant, overall and temperature-sensitive, assigned to each of the lines, is based on limited data from their responses to the isolates tested through the UKCPVS in recent years.

The lines Lr1, Lr2 and Lr2b were classified as resistant in seedling tests to isolate WBRS-98-20 as they were susceptible at the lower temperature regime only (10°C). In addition, lines Lr3, Lr3bg, Lr3ka and Lr11 had been resistant in seedling tests to isolate WBRS-97-1 at 25°C. All of these lines were susceptible, or expressed an intermediate response, in the two field nurseries. The lines Lr15 and Lr26 had been seedling resistant at both temperature regimes to isolate WBRS-97-1 but were susceptible in the field suggesting contamination of the nursery. The lines Lr20, Lr21 and Lr23 were differentiated by the isolates, expressing resistance or low levels of infection to isolate WBRS-97-1 but much higher levels of an intermediate or susceptible reaction to isolate WBRS-98-20.

Resistances conferred by Lr9, Lr19, Lr24 and Lr28 were as effective as they had been in seedling tests at one or both temperatures. The adult plant resistance of Lr37 was effective.

CONTROLLED ENVIRONMENT TESTS

Winter and spring wheat cultivars which have expressed high levels of resistance to brown rust were grown in a spore-proofed glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with one of each of the following isolates of *P. recondita*.

Isolate	Origin	Virulence factors identified in seedling tests
WBRS-99-3	cv. Imp, Cambridge	WBV-2
WBRS-99-18	cv. Abbot, Suffolk	WBV-0
WBRS-99-10	cv. Rialto, Cambridge	WBV-1,2

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

Seedlings of the cultivars as well as those of a number of newly introduced spring and winter wheats were grown to the second leaf stage and inoculated with the same isolates under conditions identical to the adult plants.

Results

These are given in Table 7. Assessments of flag leaf and seedling infection were made by reaction type and classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4) and were made 10 days post-inoculation at 25°C and 26 days post-inoculation at 10°C.

The majority of the cultivars, including the Thatcher-Lr backcross lines, carried effective adult plant or overall resistance to the isolates. Isolate WBRS-99-10 overcame the resistances of some of the cultivars at both temperature regimes. These include cvs Claire, Genghis, Buchan, Reaper and Cockpit which have previously expressed high levels of resistance. Virulence identified in controlled climate tests is not always reproduced in the field so this isolate will need to be tested in field nurseries to confirm any increased virulence. Cultivar Gamin (WBR-6) was susceptible to isolates WBRS-99-3 and WBRS-99-10 suggesting that they carry virulence factor WBV-6 in addition to those identified in seedling tests.

The Thatcher-Lr backcross lines were resistant, although Lr37 expressed resistance to two of the isolates at only the lower temperature. Lines carrying temperature-sensitive resistances which were overcome by one or more of the isolates at 10°C as seedlings were resistant at this temperature as adult plants. Cultivars Isengrain, NSL WW/27 and CWW 97/4 were susceptible although some plants of the cultivars were resistant to specific isolates whilst others were susceptible. Cultivar CPBT W59 carried a temperature-sensitive resistance effective at the higher temperature regime.

Table 5 †Percentage infection of spring and winter wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1999

Isolate/Cultivar	[NIAB rating]	WBR-	Resistance type	Virulence identified	WBRS-98-20 (WBV-1,2,7)	WBRS-97-1 (WBV-0)
Clement		1	OR	I	9	0
Rialto	[4]	1+	OR	I	1 MS	0
Fundin		2	OR*	I	27	20
Norman		2+	OR*	I	7	0.3
Hobbit		2+	OR*	I	10 MS	1
Huntsman		5	APR	I	27	19
Gamin		6	APR	I	3 MS	0.1
Sterna		7	OR*	I	10	0
Chablis	[5]	7	OR*	I	24	8
Shiraz	[9]	7+	OR*		0	0
Ranger		8	APR	I	0	0
Kinsman			APR	I	0	0
Avalon		9	APR*	I	1	1
Buster	[2]		APR*	I	8	8
Spark			APR*	I	2 MS	0.1
Hereward	[7]		APR*	I	Trace	Trace
Consort	[5]		APR	I	0.5	0.5
Axona	[9]		APR*		0	0
Paragon	[9]		APR*		0	0
Claire	[9]		APR	C	0	0
Malacca	[8]		APR	N	Trace	0
Reaper	[9]		APR/OR*	C	Trace	0
Cantata	[8]		APR*	N	1	0
Shamrock	[4]		APR	CN	1	1
Cockpit	[9]		APR	C	1	0.1
Charger	[6]		*	I	0.5	0.3
Samoa	[(8)]		APR*	N	20 R	Trace R
Raffles	[(6)]		APR*	I	28 MR	2 MS
NSL SW-5	[(9)]				10	1
Soissons	[2]		APR	I	24	0
Imp	[5]		APR*	I	26	18
Hussar			OR	C	0	0
Abbot			OR	S	0	0
Equinox	[9]		OR		0	0
Harrier			OR	N	0	0
Madrigal	[9]		OR		0	0
Aardvark	[9]		OR		0	0
Napier	[9]		OR*		0	0
Buchan	[9]		OR*	S	0	0
Genghis	[9]		OR*	C	0	0
NFC 19606			OR*		0.2	0
Shango	[7]		OR*	N	0.4	0.5
Arina			(susceptible check)		37	35

†Mean of 3 replicates, final 2 assessment dates. All reaction types susceptible unless stated.

▪MS = mixed susceptible; R = resistant; ▪MR = mixed resistant; APR = adult plant resistance; OR = overall resistance

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

* temperature sensitive resistance to some isolates.

I = virulence identified in IGER field nurseries; N = virulence identified in NIAB spreader beds

C = virulence identified in IGER controlled climate tests; S = virulence identified in IGER seedling tests

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

Table 6 †Percentage infection of Thatcher-Lr backcross lines to specific isolates of *Puccinia recondita* in field isolation nurseries in 1999

Cultivar/ Isolate	Resistance type	Virulence identified	WBRS-98-20 (WBV-1,2,7)	WBRS-97-1 (WBV-0)
Lr 1	OR*	I	18 Int	10 Int
Lr 2a	OR*	I	18	20
Lr 2b	OR*	I	25	30
Lr 2c	OR*	I	35	35
Lr 3	OR*	I	45	45
Lr 3bg	OR*	I	45	50
Lr 3ka	OR*	I	45	40
Lr 9	OR*		0	0
Lr 11	OR*	I	45	40
Lr 13	OR/APR*	I	30	35
Lr 14a	OR*	I	50	45
Lr 15	OR*	I	50	50
Lr 17	OR*/APR	S	35 MR	30 MR
Lr 19	OR		Trace R	0
Lr 20	OR*	I	35	3
Lr 21	OR	S	30 Int	3 MR
Lr 23	OR*		40 Int	3 R
Lr 24	OR		0	0
Lr 26	OR	I	45	35
Lr 28	OR*		15 R	10 R
Lr 37	APR	S	35 MR	5 MR

†Mean of 2 replicates, final 2 assessment dates.
All reaction types susceptible unless stated.
MR = mixed resistant; R = resistant; Int = intermediate
APR = adult plant resistance; OR = overall resistance
* = temperature-sensitive resistance
I = virulence identified in IGER field nurseries
S = virulence identified in seedling tests

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

Isolate			WBRS-99-3 (WBV-2)		WBRS-99-18 (WBV-0)		WBRS-99-10 (WBV-1,2)	
Incubation Temperature Cultivar [NIAB rating]		Resistance type	10°C	25°C	10°C	25°C	10°C	25°C
NSL-SW-5		APR	R (S)	R (S)	R (S)	MR (S)	R (S)	MR (S)
Aardvark	[9]	OR	R (MR)	MR (MR)	R (R)	R (MR)	R (MR)	R (MR)
Napier	[9]	OR	R (MR)	R (MR)	R (R)	R (R)	MR (R)	MR (R)
Madrigal	[9]	OR	R (MR)	R (R)	R (R)	R (R)	R (MR)	R (MR)
Equinox	[9]	OR	R (R)	R (R)	R (R)	R (R)	MR (MR)	MR (MR)
Shiraz (WBR-7+)	[9]	OR	R (MR)	R (R)	R (MR)	R (R)	R (MR)	R (MR)
Paragon	[(9)]	APR	R (S)	MS (S)	R (S)	MS (S)	R (S)	MR (S)
Sterna (WBR-7+)		OR	MR (MS)	MR (MR)	MR (MS)	MR (MR)	S (MS)	MR (MR)
Genghis	[9]	OR	R (MR)	R (R)	R (R)	R (R)	S (MS)	MS (MS)
Buchan	[9]	OR	R (MR)	R (R)	R (R)	R (MR)	S (MS)	MS (MS)
Savannah	[9]	OR	MR (MR)	MR (MR)	MR (MR)	MR (MR)	S (S)	S (S)
Reaper	[9]		R (S)	MR (S)	MR (S)	MR (MR)	MS (S)	MS (MS)
Claire	[9]	APR	R (S)	MR (S)	MR (S)	MR (S)	MS (S)	MS (S)
Cockpit	[9]	APR	MR (S)	MR (S)	MR (S)	MR (S)	S (S)	MS (S)
Malacca	[8]	APR	MR (S)	S (S)	MR (S)	MS (S)	S (S)	MS (S)
Gamin (WBR-6)		APR	MS (S)	S (S)	R (S)	MR (S)	MS (S)	S (S)
NFC 197 06			-(R)	-(R)	-(R)	-(R)	-(MR)	-(MR)
CWW 97/22			-(R)	-(R)	-(R)	-(R)	-(MR)	-(MR)
Tanker	[8]		-(R)	-(R)	-(R)	-(R)	-(MR)	-(MR)
CWW 97/45			-(R)	-(R)	-(R)	-(R)	-(MR)	-(MR)
Biscay	[9]		-(MR)	-(MR)	-(R)	-(R)	-(MR)	-(MR)
Eclipse	[9]		-(MR)	-(MR)	-(MR)	-(MR)	-(R)	-(MR)
Isengrain			-(S)	-(S)	-(S)	-(MR/S) †	-(MS)	-(MS)
NSL WW/27			-(MS)	-(MS)	-(MS)	-(MR/S) †	-(MS)	-(MS)
CWW 97/4			-(S)	-MS	-(S)	-(MS)	-(S)	-(MR/S) †
CPBT W59			-(MS)	-(MR)	-(MS)	-(MR)	-(MS)	-(MR)
Thatcher backcross line								
Lr 9		OR	R (R)	R (R)	R (R)	R (R)	R (MR)	R (R)
LR 17		OR/APR	MR (S)	MR (MR)	R (S)	R (MR)	MR (MS)	R (MR)
LR 19		OR	R (R)	R (R)	R (R)	R (R)	R (R)	R (R)
LR 21		OR	MR (MR)	MR (MR)	MR (R)	MR (R)	MR (R)	MR (MR)
LR 23		OR	MR (S)	MR (R)	R (S)	R (MR)	R (S)	R (R)
LR 24		OR	R (MR)	R (R)	MR (R)	MR (R)	R (R)	MR (R)
LR 28		OR	R (R)	R (R)	R (R)	R (R)	R (R)	R (R)
LR 37		APR	R (S)	S (S)	R (S)	MS (S)	MR (S)	MR (S)

*Adult plant and seedlings assessed on reaction type on a 0-4 scale. Resistant (R): 0-2; Susceptible (S): 3-4.

When more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response. MS = mixed susceptible; MR = mixed resistant.

Seedlings assesed on 1st leaf. Adult plants assessed on flag leaf.

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

APR = adult plant resistance; OR = overall resistance;

†Individual plants of a single cultivar show different reactions

BROWN RUST OF WHEAT: NIAB ADULT PLANT TESTS

J D S CLARKSON and S J MANN

National Institute of Agricultural Botany, Huntingdon Rd, Cambridge CB3 0LE, UK

METHODS

A reduced number of tests had to be performed in 1999, due to unfavourable sowing conditions in autumn 1998. Cultivars grown in outdoor spreader beds (winter wheat: isolate 96-1, isolate mixture; spring wheat: all tests) and polythene tunnels (winter wheat: isolate mixture) were inoculated with isolates of *Puccinia triticina* Eriks. (*P. recondita* f sp *tritici*) (Anikster *et al*, 1997), as part of the Recommended List testing programme funded by HGCA. Methods were similar to those employed in recent years; some older "control" cultivars were also included. Details of the isolates used are shown in Table 1. Results are expressed as the mean percentage leaf area infected (2 replicates) at the GS75 assessment, the latter giving the best distinction between cultivars.

Table 1 Brown rust isolates used in tests, Cambridge, 1999

Isolate number	Probable virulence factors	Source of isolate
WBRS 96-1	WBV 3,4,6	cv Caxton, Sussex, 1996
WBRS 97-3	WBV 1,2,7	cv Chablis, Lincs, 1997
NIAB 98/1	WBV 6?	cv Buster, Cambs, 1998
NIAB 98/3	WBV 1,2,6	cv Rialto, Cambs, 1998

RESULTS

High levels of brown rust infection were readily established in 1999: a year in which infection was common and sometimes severe in commercial wheat crops.

Table 2 shows that many Recommended List cultivars of winter wheat have good resistance (rating 8 or 9) to brown rust and exhibited no, or only slight, infection in these tests. However, a number of cultivars are very susceptible, *eg* Buster, Riband, Soissons, while other ostensibly less susceptible cultivars, *eg* Charger, Consort, Shamrock, have shown significant infection under these conditions of high disease pressure. It was not possible to ascertain specific cultivar/isolate interactions, as only one individual isolate was able to be tested.

Of the current NIAB Recommended spring wheat cultivars, three (Axona, Paragon, Shiraz) have good brown rust resistance and two (Chablis, Imp) are susceptible. The situation with regard to Chablis is interesting: occasional isolates have been recovered from this previously resistant cultivar in recent years, although these isolates did not always re-infect it in field tests (Clarkson & Mann, 1998; Jones, 1997, 1998). Virulence appears to be at a low level for WBR 7, the resistance factor carried by Chablis (Jones, 1998). However, in these tests, Chablis exhibited moderate to high levels of infection with all four isolates, regardless of their virulence spectrum.

ACKNOWLEDGEMENT

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

REFERENCES

Anikster, Y, Bushnell, W R, Eilam, T, Manisterski, J & Roelfs, AP (1997). *Puccinia recondita* causing leaf rust on cultivated wheats, wild wheats and rye. *Canadian Journal of Botany* 75, 2082-2096.

Clarkson, J D S & Mann, S J (1999). Brown rust of wheat: NIAB adult plant tests. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp 43-45.

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

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

Table 2 Mean % infection of winter & spring wheat cultivars by brown rust isolates in field tests, 1999

	VARIETY	ISOLATE... NIAB RATING*	WBRS 96-1 (V3,4,6)	WBRS 97-3 (V1,2,7)	NIAB 98/1 (V6?)	NIAB 98/3 (V1,2,6)	ISOLATE MIXTURE#
WW	AARDVARK	9	0	x	x	x	0
	ABBOT	9	0.0	x	x	x	0
	BUCHAN	**9**	0	x	x	x	0
	CLAIRE	**9**	1.8	x	x	x	0.8
	COCKPIT	9	0.8	x	x	x	2.5
	ECLIPSE	9	4.7	x	x	x	5.8
	EQUINOX	**9**	0	x	x	x	0
	GENGHIS	9	0	x	x	x	0
	HARRIER	9	0	x	x	x	0
	HUSSAR	9	0.8	x	x	x	0.3
	MADRIGAL	**9**	0	x	x	x	0
	NAPIER	**9**	0.2	x	x	x	0
	REAPER	**9**	0	x	x	x	0
	SAVANNAH	**9**	1.8	x	x	x	5.3
	MALACCA	**8**	4.5	x	x	x	8.0
	HEREWARD	**7**	12.8	x	x	x	10.0
	SHANGO	7	25.0	x	x	x	16.3
	SPARK	7	16.5	x	x	x	13.8
	CHARGER	**6**	39.5	x	x	x	56.3
	CONSORT	**5**	38.0	x	x	x	35.0
	CANTATA	4	16.2	x	x	x	13.8
	RIALTO	**4**	33.2	x	x	x	45.7
	SHAMROCK	**4**	35.3	x	x	x	37.5
	RIBAND	**3**	48.3	x	x	x	54.4
	BUSTER	**2**	52.0	x	x	x	59.4
	SOISSONS	**2**	62.5	x	x	x	56.3
	AVALON		36.7	x	x	x	x
	HAVEN		42.5	x	x	x	x
	MERCIA		32.5	x	x	x	x
	PASTICHE		18.3	x	x	x	x
	SLEJPNER		44.2	x	x	x	x
	VIRTUE		30.0	x	x	x	x
SW	**AXONA**	**9**	2.5	0	0	0.1	x
	PARAGON	**9**	0	1.5	0	1.5	x
	SHIRAZ	**9**	0	0.5	0	0	x
	MORPH	8	7.5	12.5	17.5	17.5	x
	CHABLIS	**5**	22.5	40.0	57.5	47.5	x
	IMP	**5**	45.0	35.0	40.0	45.0	60.0
	RAFFLES	5	55.0	25.0	42.5	22.5	x
	SAMOA	5	40.0	67.5	60.0	17.5	x
	FURY	*2*	60.0	92.5	62.5	75.0	55.0
	ALEXANDRIA		80.0	65.0	55.0	52.5	35.0

x not tested.

* 1-9 scale (1=susceptible; 9=resistant). NIAB Recommended List 2000 varieties in **bold type**.

Mixture of 96-1, 97-3, 98/1, 98/3.

MILDEW OF BARLEY

S E SLATER and J D S CLARKSON

National Institute of Agricultural Botany, Huntingdon Road, Cambridge CB3 0LE, UK

Virulence frequencies were similar to previous years, with *Vra*, *Vg*, *V(CP)*, *Va12* and *Va7* present at high levels in all populations. Frequencies of *Vh*, *Va7*, *VLa* and *V(Ab)* varied over the season, reflecting the presence of *Mla7* and *Mlh* in winter cultivars and *MlLa* and *Mla1* in spring cultivars. *Vh* was more common in isolates taken from infected leaves of cultivars carrying *Mlh*. The trend towards more complex isolates continued and the heterogeneous nature of the barley mildew population was sustained. The barley mildew population was again capable of infecting the majority of cultivars in NIAB Recommended List trials. Only spring barley cultivars with *mlo* were resistant, with NIAB ratings of 9. Some isolates continued to give increased levels of infection on the *mlo* differentials Apex and Riviera in tests. No new resistances were identified, although Vanessa may carry new, unknown resistance.

INTRODUCTION

Infections of powdery mildew on barley were common on winter cultivars in NIAB trials in spring 1999. Emerging spring cultivars quickly became infected in some areas, but subsequent development of the disease declined. Successful sampling was carried out in April, May and early June, but the majority of samples collected after this period failed to produce viable conidia.

METHODS

Virulence survey

157 samples were collected from infected leaves in 1999, all from NIAB Recommended List trial plots. 34 samples failed to produce viable conidia but single colony isolates were cultured from the remaining 123 samples. The 228 isolates tested were collected from the following 6 locations:

Headley Hall, Yorks.	75	isolates
NIAB HQ, Cambridge	70	
Bridgets, Hants.	40	
Ashford, Kent	40	
Harper Adams, Shropshire	2	
Cockle Park, Northumberland	1	
Total	228	

Isolates were collected from the following 17 spring and 22 winter cultivars:

Spring cultivars

Prisma	8	isolates	Dandy	5	isolates	Derkado	4	isolates
Tavern	7		Century	4		Static	4	
Optic	7		Chalice	4		Decanter	2	
Cooper	6		Chariot	4		Saloon	2	
Berwick	6		Chime	4		Landlord	1	
Riviera	6		Delibes	4				

Winter cultivars

Antonia	11	isolates	Vanessa	8	isolates	Muscat	6	isolates
Artist	10		Angela	7		Pastoral	6	
Regina	9		Vertige	7		Gleam	5	
Flute	8		Fanfare	6		Halcyon	5	
Heligan	8		Hanna	6		Melanie	5	
Jewel	8		Intro	6		Siberia	5	
Pearl	8		Manitou	6		Epic	2	
Rifle	8							

Single colony isolates were also taken from plants of the susceptible spring cultivar Golden Promise which had been 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. Some isolates were also tested on the winter barley cultivar Vanessa.

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
Simon	*Mlk, Mla9*	6a, 8
Apex	*mlo*	9
Riviera	*mlo*	9
Digger	*Mla13*	10a
Ricardo	*Mla3*	11

Virulence for mlo cultivars

Further experiments to evaluate the infection observed on cultivars carrying the *mlo* resistance in some differential tests were performed in 1999. The tests carried out in 1998, comparing isolates designated Apex + or Apex 0 (Apex x 1998) from their reaction on Apex in differential tests, were repeated twice. 1999 isolates collected from cultivars with *mlo* resistance, isolates that had given some infection on Apex and Riviera, the *mlo* differentials, and a selection of the 1998 Apex + isolates were tested on a range of *mlo* cultivars.

RESULTS AND DISCUSSION

Virulence

The results of the 1999 survey are shown in Table 2. Frequencies for most of the virulences were similar in all populations sampled. However, small differences were observed *eg* the majority of virulence frequencies were higher in the leaf samples, due to the particularly diverse nature of mildew populations on cultivars in trials.

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 1999

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	69	58	62	55	34	55	9
Vra	100	100	100	100	100	100	24
Vg	97	97	97	92	98	97	12
V(CP)	97	96	97	89	96	96	4
Va6	33	31	24	25	17	25	5
VLa	90	90	88	76	95	95	<1
Va12	91	89	78	76	87	93	25
Vk1	72	72	64	69	61	58	0
Va7	86	86	80	90	79	85	21
V(Ab)	81	79	55	55	74	80	21
Va1	75	73	52	50	66	61	1
Va9	28	26	24	23	20	25	<1
vo	0	0	0	0	0	0	20
Va13	13	13	22	37	11	21	<1
Va3	1	1	3	1	1	1	0
No. of isols.	228		100	101	100	100	

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

NIAB (1999)

Vra, *Vg*, *V(CP)* and *Va12* occurred at a high level in all samples, with *Vra* again at 100%. The June roof sample tended to possess slightly lower levels of the virulence factors corresponding to the resistance factors currently found only in winter cultivars *eg Vh*, *Va6* and *Va7*. Frequencies of V(A*b)* and *Va1* were lowest in the March roof sample. At this time of the year, selection pressure is exerted by winter cultivars but the resistances corresponding to these virulence factors are found only in spring cultivars.

For several years the levels of *Vra*, *Vg* and *V(CP)* have been considered fixed in the population despite fluctuations in selection pressure. However, the difference between the non-corresponding virulence and the value for all leaf data for *Vh* suggests that this virulence still responds to a reduction in selection. Many isolates taken from cultivars lacking *Mlh* did not carry *Vh*.

Table 3 compares the virulence frequencies for 1992 to 1999. There has been little change in the frequencies of *Vra*, *Vg*, *V(CP)* and *Va6* over the last few years despite variable selection pressure. The area of cultivars carrying *Mlg* was 9% in 1993, rose to 42% in 1997 but subsequently fell to 12% in 1999 but the corresponding virulence *Vg* remained around 95%.

Table 3 Virulence frequencies in barley mildew, 1992 to 1999

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

* Mean of leaf samples and random samples of airborne spores for each year. Data from Mitchell & Slater (1993, 1994, 1995), Clarkson & Slater (1996) and Slater & Clarkson (1997, 1998, 1999).

\- No data

VLa and *Va1* have been steadily increasing in frequency since 1992. This increase was attributed to the popularity of spring cultivars with *MlLa* and *Mla1*, *eg* Delibes, Chad, Cork (*Ml(Ab),Mla1*) and Cooper (*MLa,Mla1*) in the mid 1990s. However, despite a decrease in the use of these cultivars in the last four years, the corresponding virulence frequency has continued to rise. The frequency for virulence corresponding to *Mla12, Ml(Ab)* and *Mla7* has also increased: this can be related to the increase in the use of cultivars with the corresponding resistance. Optic (*Mla12,Ml(Ab)*) now occupies nearly 50% of the spring barley area, while over 30 % of the winter barley area is sown with Regina (*Mla7*).

There has been a decrease in the frequency of *Vh* in 1999, corresponding to a decline in the use of cultivars with *Mlh*. Unlike *Vra*, *Vg* and *V(CP)*, *Vh* still responds to a decrease in selection pressure. *Vk1*, *Va9* and *Va13* continued to decrease as selection for these virulence factors declined.

Complexity of isolates

Table 4 compares the number of virulence factors carried by isolates tested in 1992 - 1999. The trend towards more complex isolates observed in recent years continued. The majority of isolates examined in 1999 carried at least eight virulence factors with many isolates possessing 12 factors. As in previous years the leaf isolates carried more virulence factors than the isolates derived from the air spora.

Table 4 Comparison of the complexity of isolates collected from 1992 to 1999

Number of	% Frequency of isolates with each number of virulences*							
virulence factors	1992	1993	1994	1995	1996	1997	1998	1999
0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	<1	0	<1	<1	0	0	0
3	<1	<1	0	<1	1	0	<1	0
4	<1	4	1	1	1	1	1	1
5	2	18	4	4	3	4	4	1
6	8	34	10	11	7	11	10	8
7	20	27	24	19	14	17	15	10
8	35	10	25	28	22	23	22	21
9	25	4	16	20	24	21	18	18
10	7	1	12	10	16	16	20	25
11	3	<1	4	5	10	4	6	12
12	<1	0	2	1	8	2	2	3
13	0	0	0	0	3	<1	<1	1
Total number of isolates	463	628	539	552	428	551	743	629

* includes all virulences listed in Table 2

Fewer pathotypes were identified in 1999 (see Table 5). The two most commonly identified pathotypes were *Vh,Vra,Vg,V(CP),VLa,Va12,Vk1,Va7,V(Ab),Va1* (8% of the isolates) and *Vh,Vra,Vg,V(CP),Va6,VLa,Va12,Vk1,Va7,V(Ab),Va1* (6%). Of the 202 pathotypes identified, 113 were represented by only a single isolate.

Table 5 Number of pathotypes identified, 1995-1999

	Total number of isolates tested	Number of pathotypes
1995	552	298
1996	428	238
1997	551	277
1998	743	302
1999	629	202

Infection of barley cultivars

The barley cultivars in 1999 NIAB RL trials and the proportion of the population to which they are potentially susceptible are shown in Table 6. The majority of the winter cultivars are at risk from over 80% of the mildew population. However, a few of these cultivars exhibit moderate levels of non-specific resistance, as indicated by their high NIAB ratings *eg* Flute (8). Pearl, also with a rating of 8, carries specific resistance with corresponding low virulence (*Mla6*: 26% in Table 3), in addition to good non-specific resistance.

Table 6 The proportion of mildew isolates tested in 1999 able to infect the barley cultivars in Recommended List trials (NIAB rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Halcyon (7)	100	Jewel (7)	87
Hanna (4)	100	Regina (3)	85
Heligan (3)	100	Angela (8)	58
Intro (6)	100	Melanie (6)	58
Muscat (6)	100	Siberia (7)	58
Pastoral (3)	100	Vertige (5)	50
Antonia (6)	97	Manitou (5)	25
Fanfare (5)	97	Gleam (6)	22
Flute (8)	87	Pearl (8)	22
Spring cultivars	**Proportion (%)**	**Spring cultivars**	**Proportion (%)**
Optic (7)	69	Dandy (9)	0
Prisma (3)	69	Decanter (9)	0
Tavern (6)	64	Derkado (9)	0
Cooper (7)	61	Hart (9)	0
Delibes (6)	51	Landlord (9)	0
Century (9)	0	Riviera (9)	0
Chalice (9)	0	Saloon (9)	0
Chariot (9)	0	Static (9)	0
Chime (9)	0		

The majority of the spring cultivars carry *mlo* resistance, which is not yet matched by virulence in the mildew population. The five non-*mlo* cultivars are susceptible to over half the population, although Optic and Cooper have moderate non-specific resistance.

Virulence for *mlo* cultivars

In earlier experiments, isolates giving some infection on the *mlo* differential, Apex, have subsequently failed to infect mlo cultivars. Generally, this occasional infection could be related to variation between batches of tests, suggesting an environmental origin. However, tests in 1998 and 1999 suggest there may have been a shift in the population towards an increased level of aggressiveness for *mlo* resistance.

The tests with isolates designated Apex + and Apex 0 from 1998 were repeated in 1999. The actual infection levels varied between tests, but generally the Apex + isolates gave the highest infection in all four tests. The isolates collected from *mlo* cultivars gave the highest levels of infection in test 1 but intermediate levels in tests 2 - 4. In all four tests, the isolates designated Apex 0 gave the lowest numbers of colonies

The results of a further test carried out with 1999 isolates and a selection of 1998 isolates 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

original designation of isolates	Year collected	no. of isolates	Chariot	Landlord	Riviera	Chalice	Apex
Apex 0	1970	1	0	0	0	0	0
Apex 0	1998	2	0	0	0	1.3	0
Apex +	1998	5	5.0	0.8	6.0	12.0	8.5
Apex +	1999	12	1.9	0.3	2.2	5.3	4.5

Occasional colonies were observed on *mlo* cultivars tested with isolates from field plots of *mlo* cultivars in 1999. Chalice generally supported more colonies that Chariot, Riviera and Apex, regardless of the origin of the isolates.

Table 8 Proportion of isolates infecting Apex and Riviera in differential tests, 1996-1999

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

For several years sporadic infection of Apex has been observed in differential tests and for the last four years, Riviera was also included. Table 8 shows the number of isolates giving low levels of infection on Apex and Riviera in 1996 - 1999. Although the number of isolates infecting Apex has remained constant, more isolates in 1998 and 1999 appeared able to infect Riviera.

Resistance factors in new cultivars

The specific resistance factors carried by cultivars in NIAB RL trials in 1999 are shown in Table 9. No new virulence factors or combination of factors were identified. However, the winter barley cultivar Vanessa appears to possess specific resistance not included in the differential set. 4% of the isolates tested carried virulence for Vanessa but only the frequently occurring virulence factors *Vra* and *Va7* were common to all the Vanessa-virulent isolates.

Table 9 Specific resistance genes of barley cultivars (2000 Recommended List cultivars in **bold**)

None	*Mla12*	*Ml(La),Mla1*
Halcyon (W)	**Flute** (W)	**Cooper** (S)
Hanna (W)	**Jewel** (W)	
		Ml(Ab),Mla1
Mlra	*Mlh,Mla12*	**Delibes** (S)
Halifax (W)	Artist (W)	
Heligan (W)		*mlo*
Hurricane (W)	*Mlra,Mla12*	Alexis (S)
Intro (W)	Rifle (W)	Annabell (S)
Muscat (W)		Barke (S)
Pastoral (W)	*Mlh,Mlra,Mla12?*	Berwick (S)
	Mariner (W)	**Century** (S)
Mlh,Mlra		**Chalice** (S)
Angela (W)	*Mla9*	**Chariot** (S)
Melanie (W)	**Manitou** (W)	Chaser (S)
Siberia (W)		**Chime** (S)
	Mla7 (Mlra?)	**Dandy** (S)
Mlh, Mlg	**Regina** (W)	**Decanter** (S)
Antonia (W)		**Derkado** (S)
	Mlh,Mlra,Mla7	**Hart** (S)
Mlra,Mlg,Ml(CP)	**Vertige** (W)	**Landlord** (S)
Fanfare (W)		Otira (S)
Opal (W)	*Mla13*	**Riviera** (S)
	Pipkin (W)	**Saloon** (S)
Mlra,Mlg,Ml(CP),Mla6		**Static** (S)
Epic (W)	*Mla12,Ml(Ab)*	
	Optic (S)	Unknown
Mlh,Mlra,Mlg,Ml(CP),Mla6		Gaelic (W)
Gleam (W)	*Mlg,Ml(CP),Mla12,Ml(Ab)*	Fighter (W)
	Prisma (S)	Vanessa (W)
Mlh,Mlra,Mlg,Mla6		
Pearl (W)	*Mla1?*	
	Tavern (S)	

(W) winter cultivar, (S) spring cultivar

REFERENCES

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

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

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

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

NIAB (1999). Seed Production No. 22 (November 1999).

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

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

MILDEW OF BARLEY IN NORTHERN IRELAND

P C MERCER and A RUDDOCK

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

For the first time since populations of barley powdery mildew have been analysed in N. Ireland there was a complete failure to obtain any isolates. Although there was a low level of the disease early in the season, it had disappeared by the time that isolations were attempted.

The most commonly sown cultivars in N. Ireland in the season 1998/99 are shown in Table 1. As in the previous season there has been only slight change in cultivar popularity. There was a further slight decrease in cultivars carrying the *mlo* gene from 77% to 71%.

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

Spring cultivars *(resistance genes)*	**%**	**Winter cultivars** *(resistance genes)*	**%**
Riviera (*mlo*)	48	Regina (*Mlra, Mla12*)	69
Dandy (*mlo*)	18	Pastoral (*Mlra*)	20
Felicie (*Mlg, Ml(CP), Mla9*)	7	Jewel (*Mla12*)	8
Lamba (*?*)	6	Fighter(*Mlg,Ml(CP),Ml(Ab)*)	2
Delibes (*Ml(Ab), Mla1*)	5		
Landlord (*mlo*)	5		

YELLOW RUST OF BARLEY

G J HILTON and W C HUTTON

National Institute of Agricultural Botany, Huntingdon Road, Cambridge CB3 0LE, UK

One sample of barley yellow rust was received in 1999, from a crop of the winter barley cultivar Regina, in East Yorkshire. The isolate obtained from the sample possessed the virulence BYV1,2,3. This virulence combination represents all the specific virulence factors in barley known to date. The crop concerned was showing over 3 % infection on the flag leaf, and around 1 % infection on leaf two, at GS75.

This sample demonstrates the risk to the current winter barley crop, given that around 50 % of the current area is attributed to susceptible cultivars (NIAB rating=5 or lower), with around 30 % under the highly susceptible cultivar Regina (NIAB rating=2)*.

It should also be noted that around 20 % of the spring barley area is under susceptible cultivars (NIAB rating=5 or lower)*.

**NIAB Seed Production leaflet, Issue No.22, November 1999.*

VIRULENCE FREQUENCIES FOR 1981-1999

The specific resistances (BYR factors) identified in barley cultivars to date, differential cultivars possessing each resistance and the year of first detection of corresponding virulence in the UK population of *P.striiformis* are given in Table 1.

Table 1 Resistance factors to *Puccinia striiformis* and differential cultivars

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

* O = Overall, S = Seedling. Overall resistances are effective at all growth stages, seedling resistances are ineffective at adult plant growth stages.

Virulence frequencies for 1981-99 are given in Table 2.

REFERENCE

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

Table 2 Virulence factor frequencies (%) for barley yellow rust, 1981-99

	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99
BYV 1	100	100	100	100	-	-	100	-	100	100	100	100	100	100	100	-	-	-	100
BYV 2	81	96	87	100	-	-	100	-	100	0	100	100	100	100	100	-	-	-	100
BYV 3 †	-	-	17	86	-	-	22	-	75	0	0	0	0	100	0	-	-	-	100
No. of isolates	52	25	30	7	0	0	9	0	4	1	1	2	1	1	3	0	0	0	1

† Not included in tests before 1983.

BROWN RUST OF BARLEY

E R L JONES

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

The majority of the current NIAB recommended winter barleys were susceptible to brown rust although some expressed resistance in adult plant glasshouse tests to specific isolates of the pathogen. Several spring barleys were resistant as adult plants in the field and glasshouse to pathotypes carrying a range of virulences.

GLASSHOUSE SEEDLING TESTS WITH 1999 ISOLATES

The thirty-four samples of barley brown rust received in 1999 were from a range of winter barley cultivars. Twenty-two of these had been sampled from a trial site at Headley Hall, Yorkshire. The geographic origins of the samples are given in Table 1.

Table 1 Geographical origin of 1999 barley brown rust samples

Location (County)	Number of samples
Yorkshire	22
Hertfordshire	2
Devon/Cornwall	2
Essex	2
Kent	1
Cambridgeshire	1
Staffordshire	1
Sussex	1
Northamptonshire	1
Oxfordshire	1

Isolates were not cultured from all of these, selection being based on the cultivar/geographic origins of the samples. Fourteen were tested on a set of ten cultivars (Table 2) which carry different, identified Pa genes for resistance to *Puccinia hordei*.

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

Cultivar	BBR Factor	Gene symbol	Ranking for octal notation
Sudan	1	Pa_1	1
Peruvian	2	Pa_2	2
Ribari	3	Pa_3	3
Gold	4	Pa_4	4
Quinn	5	$Pa_2 + Pa_5$	5
Bolivia	6	$Pa_2 + Pa_6$	6
Cebada Capa	7	Pa_7	7
Egypt 4	8	Pa_8	8
Hordeum 2596	9	Pa_9	9
Triumph	10	Pa_{10}	10

Results

The isolates carried virulences in various, previously identified, combinations to all of the differential cultivars (Table 3) with the exception of Cebada Capa (BBR-7). Resistance conferred by this cultivar has remained effective against UK pathotypes.

Table 3 Races identified from 1999 isolates

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

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF BROWN RUST

Adult plant tests

Spring and winter barley cultivars 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	Origin
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

The plants were inoculated in a settling tower. They were placed in dew simulation chambers for 16 h at 15°C post-inoculation and then incubated in the glasshouse at approximately 15°C for 14 days. Assessments were made of percentage flag leaf area infected and of infection type. Using infection type, cultivars were classified on the standard 0-4 scale as resistant (R = 0-2) or susceptible (S = 3-4).

Seedling tests

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

Results

Winter barley

These are given in Table 4. 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 to the isolates.

Group 1: Cultivars susceptible.

Group 2: Cultivar Pearl expressed a susceptible reaction, albeit at relatively low levels, to isolate BRS-99-13. This is the least widely virulent of the three isolates but is the only one carrying virulence to BBR-5. In similar tests in 1998 cv. Pearl had also been susceptible to an isolate (BRS-98-2) carrying the same range of virulences but, as in 1999 tests, cv. Pearl expressed adult plant resistance to isolates BRS-97-2 and BRS-97-27.

Group 3: Within this group, cultivars expressed adult plant resistance effective against isolate BRS-97-27. Four of the cultivars, Hanna, Heligan, Rifle and Flute, were tested against this isolate in 1998 when they again expressed resistance. However, in contrast to the 1998 tests, in 1999 BRS-97-2 induced a susceptible reaction.

Spring barley

The responses of the spring barleys to the isolates are given in Table 5 where they are classified into groups based on similarities in the patterns of their adult plant responses to the three isolates. Cultivars within a group may be differentiated by their seedling reactions.

Group 1: Included within this group of cultivars, susceptible to all the isolates, are cvs Chariot and Chalice which were resistant as adult plants to isolates BRS-97-2 and BRS 97-27 in 1998 tests. In 1999 they expressed a mixed, mainly susceptible response to the same two isolates.

Group 2: The differential cultivars Trumph (BBR-10) and Hordeum 2596 (BBR-9) were susceptible to the two isolates carrying the corresponding virulences but resistant to isolate BRS-99-13 which lacks both. Previous years' data suggest that cv. Prisma carries BBR-10 but in similar tests in 1998 cv. Optic was resistant to BRS-97-2 at the later growth stages.

Group 3: Cultivar Landlord, like cv. Quinn (BBR-5), was only susceptible as an adult plant to the isolate (BRS-99-13) carrying virulence factor BBV-5. Seedling tests differentiated it from cv. Quinn when it was susceptible to the other isolates.

Group 4: Cultivar Egypt 4 (BBR-8) expressed adult plant resistance to isolate BRS-97-27, although this isolate has been identified in seedling tests as carrying the corresponding virulence. Previous years' tests have also shown this cultivar to express adult plant resistance to isolates identified as carrying BBV-8 in seedling tests. Cultivar Century displayed a similar pattern of responses.

Group 5: As adult plants cultivars within this group expressed a range of quantitative, resistant or mixed resistant, responses. Several of the cultivars were differentiated by their seedling reactions. Group 5a cultivars were seedling resistant to isolate BRS-99-13 only, whilst cvs Static and NFC 496-20 (Group 5b) additionally expressed resistance to isolate BRS-97-27. The susceptible responses of the differential cultivars Peruvian (BBR-2) and Bolivia (BBR-6) within Group 5c confirmed the isolates as carrying the corresponding virulences. The overall resistance of cv. Cebada Capa (BBR-7) was effective.

Group 6: The resistances of cvs Estate (BBR-3) and Chime (Group 6a) were effective in seedling and adult plant tests to isolates not carrying virulence factor BBV-3. Cultivar Chaser (Group 6b) was also susceptible to isolate BRS-97-2 but, unlike cultivars in Group 6a, was seedling susceptible to all the isolates.

A number of cultivars, winters and springs, were susceptible as adult plants in 1999 glasshouse tests to isolate BRS-97-2 but had been resistant to it in similar tests in 1998, suggesting that the isolate has become contaminated with other pathotypes although seedling tests on the standard set of differential cultivars showed the isolate as carrying the same virulence factors.

ADULT PLANT TESTS IN A FIELD ISOLATION NURSERY

A spring barley nursery was sown during the 1999 season to detect any increased virulence by the pathogen under field conditions.

Twenty-five cultivars were sown within one nursery and artificially inoculated with a mixture of the following isolates:

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

These were the same isolates as used in the 1998 glasshouse tests (Jones, 1999).

Results

Good levels of disease built up on the susceptible cultivars within the nursery. Plants were assessed on percentage leaf area infected as well as on reaction type. They were classified on the standard 0-4 scale as resistant (R=0-2), or susceptible (S=3-4). The data are summarised in Table 6.

The cultivars displayed a range of quantitative responses to the mixture of isolates. Cultivar Decanter which was classified as resistant to these pathotypes in glasshouse tests expressed a mixed susceptible reaction. Conversely, cvs Chariot, Optic and Chalice, susceptible to isolate BRS-98-2 in 1998 glasshouse tests and to isolates BRS-97-2 and BRS-97-27 in 1999 tests displayed mainly resistant reactions in the field.

Cultivar Chime, thought to carry the specific resistance BBR-3 based on its responses to the isolates in the glasshouse, was resistant whereas cv. Simon, known to carry BBR-3 and cv. Chaser, which displayed a pattern of adult plant responses similar to those of cv. Chime in the glasshouse, were susceptible albeit at relatively low levels in the field.

The higher levels of resistance expressed by a few cultivars in the field than under glasshouse conditions may be due to environmental factors. The majority of cultivars however showed similar responses in both tests. These included cvs Derkado, CSBA 4315-110, Saloon, Cooper, Delibes, Static and NFC 496-20, all of which were resistant.

REFERENCES

Jones, E R L (1999). Brown rust of barley. *UK Cereal Pathogen Virulence Survey 1998 Annual Report*, pp.61-66.

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

Isolate / Cultivar [NIAB rating]		Group	BRS-99-13 (BBV-1,2,4,5,6,8) Race octal 273			BRS-97-2 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-97-27 (BBV-1,2,4,6,8,9,10) Race octal 1653		
Vertige	[6]	1	45	S	(S)	55	S	(S)	45	S	(S)
Melanie	[3]		45	S	(S)	35	S	(S)	25	S	(S)
Manitou	[4]		45	S	(S)	25	S	(S)	35	S	(S)
Vanessa	[4]		43	S	(S)	40	S	(S)	15	S	(S)
Muscat	[6]		35	S	(S)	38	S	(S)	50	S	(S)
Fanfare	[7]		35	S	(S)	25	S	(S)	20	S	(S)
12431 VHI			35	S	(S)	25	S	(S)	35	S	(S)
Regina	[6]		30	S	(S)	20	S	(S)	20	S	(S)
Gleam	[5]		30	S	(S)	33	S	(S)	25	S	(S)
Angela	[7]		30	S	(S)	30	S	(S)	13	S	(S)
Pastoral	[4]		25	S	(S)	38	S	(S)	23	S	(S)
Epic	[7]		22	S	(-)	15	S	(-)	28	S	(-)
Halcyon	[6]		20	S	(S)	20	S	(S)	25	S	(S)
Intro	[7]		28	S	(S)	22	MS	(S)	20	MS	(S)
CPBT B23			10	MS	(S)	20	MS	(S)	33	S	(S)
Pearl	[7]	2	6	MS	(S)	3	R	(S)	15	R	(S)
Hanna	[4]	3	33	S	(S)	35	S	(S)	10	MR	(S)
Heligan	[7]		38	S	(S)	35	S	(S)	15	MR	(S)
Jewel	[7]		33	S	(S)	35	S	(S)	40	MR	(S)
Rifle	[8]		35	S	(S)	20	I	(S)	12	R	(S)
Flute	[8]		30	S	(S)	25	S	(S)	15	R	(S)
Antonia	[7]		28	S	(S)	25	MS	(S)	28	MR	(S)

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

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

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

Isolate / Cultivar [NIAB rating]		Group	BRS-99-13 (BBV-1,2,4,5,6,8) Race octal 273			BRS-97-2 (BBV-1,2,3,4,6,8,9,10) Race octal 1657			BRS-97-27 (BBV-1,2,4,6,8,9,10) Race octal 1653		
Riviera	[4]	1	50	S	(S)	30	S	(S)	30	S	(S)
Dandy	[5]		30	S	(S)	35	S	(S)	40	S	(S)
Chariot	[5]		30	S	(S)	30	MS	(S)	30	MS	(S)
Chalice	[6]		28	S	(S)	25	S	(S)	15	MS	(S)
Gold	BBR-4		35	S	(S)	13	S	(S)	33	S	(S)
Sudan	BBR-1		25	S	(S)	20	S	(S)	15	S	(S)
Optic	[8]	2	3	R	(R)	35	S	(S)	35	S	(S)
Prisma	[5]		1	R	(R)	20	S	(S)	40	S	(S)
Trumpf	BBR-10		8	R	(R)	43	S	(S)	45	S	(S)
Hordeum 2596	BBR-9		19	R	(R)	15	S	(S)	30	S	(S)
Landlord	[6]	3a	23	MS	(S)	18	R	(S)	30	R	(S)
Quinn	BBR-5	3b	40	S	(S)	25	R	(R)	0	R	(R)
Century	[4]	4	35	S	(S)	35	S	(S)	5	MR	(S)
Egypt 4	BBR-8		38	S	(S)	28	MS	(S)	28	R	(S)
Derkado	[6]	5a	40	R	(R)	25	MR	(S)	15	R	(S)
CSBA 4315-110	[6]		40	R	(R)	20	MR	(S)	25	MR	(S)
Decanter	[7]		30	R	(R)	20	MR	(S)	30	MR	(S)
Saloon	[6]		18	R	(R)	28	R	(MS)	23	R	(S)
Cooper	[8]		15	R	(R)	10	R	(S)	15	MR	(S)
Delibes	[8]		15	R	(R)	10	MR	(S)	10	MR	(S)
Static	[8]	5b	6	R	(R)	30	MR	(S)	25	R	(R)
NFC 496/20	[9]		0		(R)	15	MR	(S)	0		(R)
Peruvian	BBR-2	5c	5	R	(S)	25	MR	(S)	25	R	(S)
Bolivia	BBR-6		1	R	(S)	0		(S)	5	R	(S)
Cebada Capa	BBR-7	5d	0		(R)	0		(R)	0		(R)
Chime	[7]	6a	15	R	(R)	18	S	(S)	15	R	(R)
Estate	BBR-3		0		(R)	38	S	(S)	0		(R)
Chaser	[7]	6b	3	R	(S)	25	MS	(S)	25	R	(S)

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

Table 6 Percent *infection of spring barley cultivars to *Puccinia hordei* in a field isolation nursery in 1999

Cultivar [NIAB rating]		BBR factor	% Infection	Reaction type
Midas			31	S
Hordeum 2596		BBR-9	31	S
Riviera	[4]		21	S
Prisma	[5]		18	S
Dandy	[5]		14	S
Quinn		BBR-5	9	S
Simon		BBR-3	5	S
Century	[4]		22	MS
Trumpf		BBR-10	16	MS
Vada			16	MS
Chaser	[7]		16	MS
Decanter	[7]		11	MS
Chalice	[6]		22	MR
Landlord	[6]		14	MR
Optic	[8]		6	MR
Chariot	[5]		14	R
Saloon	[6]		11	R
CSBA 4315-110	[6]		8	R
Derkado	[6]		8	R
Cebada Capa		BBR-7	6	R
NFC 496-28	[9]		4	R
Static	[8]		5	R
Cooper	[8]		4	R
Chime	[7]		2	R
Delibes	[8]		1	R

*Mean of 4 replicates, final 2 assessment dates

S = suscrptible; R=resistant; 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, U.K.
†Scottish Crop Research Institute, Invergowrie, Dundee, U.K.

Several of the current, most widely grown winter barley cultivars carry the race specific resistance BRR-2. Very few of the most popular cultivars carry resistance factors BRR-5, BRR-6 or BRR-8. Consequently virulences to these remain at a low frequency in the pathogen population. Adult plant tests in the glasshouse show many of the 1999 NIAB Recommended List varieties to be highly susceptible to one or more isolates of the pathogen against which they were tested. Cultivar Manitou, a winter barley, was highly resistant whilst the spring barley cv. Chaser, thought to carry BRR-8, also expressed good resistance. Spring barleys grown in field nurseries at IGER and SCRI showed a range of quantitative responses with infection levels lower than those seen on corresponding cultivars in glasshouse tests.

SEEDLING TESTS WITH 1999 ISOLATES

Rhynchosporium-infected leaf samples were received from 6 spring and 32 winter barley cultivars. Of these, 17 were from cv. Regina which carries a race specific resistance, BRR-2. The geographic origins of the samples are given in Table 1.

Table 1 Geographic origins (county) of *Rhynchosporium* samples received in 1999

County	No. of isolates	County	No. of isolates
Kent	1	Dorset	1
Essex	3	Somerset	1
Suffolk	2	Devon	4
Cambs	2	Cornwall	1
Lincs	1	Cleveland	1
Northants	7	Clwyd	2
Oxon	1	Powys	1
Herts	1	Dyfed	2
Hants	2	Roxburghshire	4
Avon	1		

Viable spore suspensions were obtained from 25 of the samples and were tested on a set of differential cultivars (Table 2).

Virulence to BRR-1 and BRR-2, found at increased frequencies in 1998, occurred at similar frequencies in 1999 (Table 4). This, as in 1998, is attributable to the high proportion of survey samples being received from winter barley cultivars many of which, including cv. Regina, carry BRR-2.

Five isolates carried virulence to cv. La Mesita (BRR-5) and four of these were cultured from infected leaf samples of cv. Pipkin previously identified as carrying BRR-5. Cultivar Osiris (BRR-6) was susceptible to four of these isolates, where the corresponding virulence BRV-6, which remains at relatively low frequency, was combined with BRV-5 (Table 3).

Cultivar Digger (BRR-8) was classified as resistant to the 1999 isolates although some did induce low levels of infection (<5%) on this cultivar which has been resistant to all but a few survey isolates in recent years.

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-99-16	3,5,6 (64)	cv. Pipkin, Suffolk
RS-99-32	1,2,3,4,7 (117)	cv. Chariot, Roxburghshire
RS-99-20	1,2,3 (7)	cv. Regina, Warwickshire

† identified in seedling tests

The plants were inoculated by spraying with a spore suspension, placed in dew simulation chambers at 15°C for 48 h post inoculation and then incubated in the glasshouse at approximately 15°C for 16 days. Assessments were made of percentage flag leaf area infected.

Seedling tests

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

Table 2 Differential test cultivars for *Rhynchosporium secalis*

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

Results

The isolates carried a range of virulences in various, previously identified combinations (Table 3).

Table 3. Virulence factor combinations (octal races) identified from the 1999 isolates

No. of isolates	Race octal
1	14
2	64
1	134
2	174
6	7
8	17
1	107
4	117

The frequencies of individual virulences are given in Table 4

Table 4. Frequencies of individual virulences in 1999 isolates

BRV	8	7	6	5	4	3	2	1
Frequency	0	0.32	0.16	0.20	0.64	1.0	0.76	0.76
No. of isolates = 25								

Winter barley

Data from seedling and adult plant tests are given in Table 5. Cultivars are grouped within the table on the basis of similarities in the patterns of their responses to the isolates. It should not be interpreted that cultivars within a group carry a common resistance factor(s).

Group 1: Cultivars were susceptible as adult plants and seedlings to the three isolates.

Group 2: These cultivars, which include cv. Astrix (BRR-2), were resistant to isolate RS-99-16 which lacks virulence to BRR-1 and BRR-2. Cultivar Muscat has previously been susceptible to some isolates not carrying virulence factors BRV-1 and BRV-2. The responses of cv. Angela to the isolates against which it was tested in similar tests in 1998 suggested it carried BRR-5 in common with cv. Pipkin but in 1999 tests it was resistant to isolate RS-99-16 which carries the corresponding virulence BRV-5.

A number of newly introduced cultivars were included in this group on the basis of the patterns of their seedling reactions.

Group 3: Cultivars Pirate (BRR-7) and Igri (BRR-3) were susceptible to RS-99-32, the only isolate in these tests previously identified as carrying virulences BRV-7 and BRV-3. Adult plants of these cultivars were also infected, albeit at relatively low levels, by isolate RS-99-20 but were seedling resistant.

Group 4: The race specific resistance BRR-5, carried by cv. Pipkin, has previously been shown to be ineffective at later growth stages to a number of isolates not identified as carrying the corresponding virulence gene in seedling tests (Jones and Clifford, 1982). Isolate RS-99-16, which carries BRV-5, was the only isolate to overcome the seedling resistance of cvs Pipkin and Leonie.

Group 5: Cultivar Manitou has expressed high levels of resistance at the seedling and/or adult plant stages of growth to a number of isolates against which it has been tested in the glasshouse in recent years. In 1999 seedling tests its resistance was overcome only by isolate RS-99-16 which failed to infect it as an adult plant.

Spring barley

Table 6 shows that the majority of the spring barleys were susceptible to the test isolates. Those expressing resistance to one or more of the isolates were grouped within the table on the basis of similarities in the patterns of their adult plant and seedling responses to the isolates. These comprised mainly the seedling differential cultivars which carry known specific resistances. It should not be interpreted that cultivars within a group carry a common resistance of factor(s).

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-99-16 (Race octal 64) BRV-3,5,6	RS-99-32 (Race octal 117) BRV-1,2,3,4,7	RS-99-20 (Race octal 7) BRV-1,2,3
Pastoral [7]	1	40 (S)	80 (S)	75 (S)
Fanfare [8]		43 (S)	55 (S)	65 (S)
Antonia [8]		35 (S)	48 (S)	43 (S)
Pearl [8]		20 (S)	70 (S)	65 (S)
Flute [8]		23 (S)	43 (S)	75 (S)
Rifle		13 (S)	80 (S)	75 (S)
Vertige [5]		18 (S)	65 (S)	55 (S)
Jewel [8]		10 (S)	75 (S)	75 (S)
Opal [7]		- (S)	- (S)	- (S)
Sumo [4]		- (S)	- (S)	- (S)
CPBT B 27		- (S)	- (S)	- (S)
NSL 95-6850		- (S)	- (S)	- (S)
Avenue [6]		- (S)	- (S)	- (S)
Athene BRR-3		50 (S)	80 (S)	70 (S)
Intro [6]	2	0 (R)	80 (S)	90 (S)
Regina [8]		0 (R)	83 (S)	80 (S)
Heligan [7]		0 (R)	80 (S)	85 (S)
Angela [8]		0 (R)	75 (S)	85 (S)
Muscat [8]		1 (S)	70 (S)	70 (S)
Hanna [8]		1 (R)	65 (S)	85 (S)
Halcyon [5]		0 (R)	70 (S)	40 (S)
Melanie [8]		0 (R)	- (S)	70 (S)
Vanessa [8]		0 (R)	31 (S)	50 (S)
CPBT B 23		0 (R)	53 (S)	35 (S)
Gleam [7]		0 (R)	9 (S)	58 (S)
12431 VH 1		0 (R)	18 (S)	15 (S)
CE-4-3203		- (R)	- (S)	- (S)
CPBT B 31		- (R)	- (S)	- (S)
Carola		- (R)	- (S)	- (S)
Siberia [7]		- (R)	- (S)	- (S)
Artist [7]		- (R)	- (S)	- (S)
Astrix BRR-2		1 (R)	60 (S)	60 (S)
Pirate BRR-7	3	0 (R)	43 (S)	10 (R)
Igri BRR-4		0 (R)	33 (S)	10 (R)
Pipkin [4]	4	40 (S)	53 (R)	35 (R)
Leonie [9]		- (S)	- (R)	- (R)
Manitou [8]	5	0 (S)	0 (R)	1 (R)

*Adult plants assessed on percentage area of flag leaf infected. Mean of 2 plants. Seedlings assessed on 2nd leaf on a 0-9 scale and classified as resistant (R=0-4) or susceptible (S=5-9). [ ] NIAB rating: 1 = susceptible; 9 = resistant

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

Cultivar/Isolate [NIAB rating]		Group	RS-99-16 (Race octal 64) BRV-3,5,6	RS-99-32 (Race octal 117) BRV-1,2,3,4,7	RS-99-20 (Race octal 7) BRV-1,2,3
Static	[5]	1	80 (S)	85 (S)	85 (S)
Chariot	[3]		80 (S)	80 (S)	85 (S)
Chalice	[5]		75 (S)	85 (S)	70 (S)
Prisma	[6]		70 (S)	85 (S)	70 (S)
Chime	[5]		70 (S)	70 (S)	85 (S)
Saloon	[5]		70 (S)	80 (S)	80 (S)
Riviera	[6]		75 (S)	65 (S)	75 (S)
Decanter			60 (S)	75 (S)	85 (S)
		[5	60 (S)	75 (S)	60 (S)
	]		60 (S)	70 (S)	70 (S)
Delibes	[7]		50 (S)	70 (S)	70 (S)
Landlord			50 (S)	70 (S)	55 (S)
		[6	35 (S)	80 (S)	55 (S)
	]		25 (S)	70 (S)	75 (S)
Cooper	[5]		20 (S)	60 (S)	70 (S)
CSBA 4315-110			10 (S)	70 (S)	65 (S)
Dandy	[7]				
NFC 496-20			0 (R)	65 (S)	80 (S)
Optic	[4]				
Derkado	[3]		80 (S)	35 (R)	55 (R)
			70 (S)	20 (R)	15 (R)
Armelle	BRR-1	2			
			35 (S)	0 (R)	0 (R)
La Mesita	BRR-5	3			
Century	[8]		8 (R)	3 (R)	1 (R)
			5 (R)	0 (R)	0 (R)
Osiris	BRR-5	4			
Digger	BRR-8	5			
Chaser	[8]				

* Adult plants assessed on percentage area of flag leaf infected. Mean of 2 plants. Seedlings assessed on 2nd leaf on a 0-9 scale and classified as resistant (R=0-4) or susceptible (S=5-9).

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

Group 1: Cultivars susceptible.

Group 2: The resistance factor BRR-2 carried by cv. Armelle was effective in adult plant and seedling tests against isolate RS-99-16 which lacks the corresponding virulence BRV-2 which is carried by the other two isolates.

Group 3: Isolate RS-99-16, the only one to overcome the resistances of cvs La Mesita (BRR-5) and Century in seedling tests also induced the highest levels of infection on adult plants of these cultivars. Cultivar Century was seedling susceptible to two non-BRV-5 carrying isolates in 1998 glasshouse tests.

Group 4: Virulence factor BRV-6 remains at a low frequency in the UK pathogen population (Table 4). However, it was identified in isolate RS-99-16 in survey seedling tests where it overcame the overall resistance of cv. Osiris (BRR-6).

Group 5: Cultivars Digger (BRR-8) and Chaser responsed similarly to the isolates. As seedlings they were classified as resistant, although some plants were infected at very low levels. Adult plants of cv. Digger also showed low levels of infection to all isolates as did cv. Chaser to isolate RS-99-16.

ADULT PLANT FIELD ISOLATION NURSERY AT IGER

A spring barley nursery was sown during the 1999 season on a site conducive to the development of leaf scald. Cultivars comprised those on the 1999 NIAB Recommended List of spring barleys, together with cultivars carrying known specific resistances.

Results

Reasonable levels of disease built up on the susceptible cultivars which were assessed throughout the season by percentage leaf area infected. The cultivars expressed a range of quantitative responses to the naturally introduced pathotypes with infection levels (Table 7) being generally much lower than those on the corresponding cultivars in adult plant glasshouse tests.

Cultivars Chaser and Century which were highly resistant in the field were also resistant in glasshouse tests where their responses to test isolates suggested they carried resistance factors BRR-8 and BRR-5 respectively. Neither of the corresponding virulences (BRV-8 and BRV-5) were carried by the pathotypes which infected the field nursery. Glasshouse seedling tests showed that the field isolates carried virulence factors BRV-3 and BRV-4 (race octal 14).

FIELD NURSERY AT SCRI

A nursery comprising the 1999 NIAB Recommended List of spring barleys, together with cultivars carrying known specific resistances, was sown during the spring of 1999. Cultivars within the nursery became infected with naturally occurring pathotypes. The nursery was irrigated to encourage the development of disease.

Table 7 Infection* of spring barley cultivars to specific isolates of *Rhynchosporium secalis* in a field isolation nursery in 1999

Cultivar	[NIAB rating]	Mean % infection
Optic	[4]	22
Riviera	[6]	19
Landlord	[6]	15
Chime	[5]	15
Chariot	[3]	14
Saloon	[5]	14
NFC 496-20		14
CSBA 4315-110		13
Cooper	[5]	12
Static	[5]	11
Delibes	[7]	10
Derkado	[3]	8
Decanter	[5]	8
Chalice	[5]	8
Dandy	[7]	3
Prisma	[6]	1
Chaser	[8]	0.3
Century	[8]	0.1
Armelle	BRR-1	3
La Mesita	BRR-5	2
Osiris	BRR-6	1
Digger	BRR-8	0

*Mean of 3 replicates, final 2 assessment dates

Results

Assessment of percentage leaf area infected was made and results are given in Table 8. The cultivars expressed a range of quantitative responses to the pathotypes with the most susceptible cultivars becoming quite heavily infected. A number of cultivars showed high levels of resistance including cvs Century and Chaser which, based on data from glasshouse tests, are thought to carry resistance factors BRR-5 and BRR-8 respectively. Neither of the corresponding virulences were carried by the pathotypes which invaded the nursery as all the differential cultivars including cvs La Mesita (BRR-5) and Digger (BRR-8) were resistant.

Table 8 Percentage infection of barley cultivars in the SCRI *Rhynchosporium* field nursery in 1999

Cultivar	[NIAB rating]	Resistance factor (BRR-)	Mean % infection
Cooper	[5]		33
Optic	[4]		33
Derkado	[3]		29
Decanter	[5]		18
Chalice	[5]		16
CSBA 4315-110			12
Static	[5]		10
Saloon	[5]		6
Prisma	[6]		6
Chime	[5]		6
Chariot	[3]		5
Landlord	[6]		5
Delibes	[7]		5
Riviera	[6]		5
NFC 496-20			4
Dandy	[7]		1
Century	[8]		1
Chaser	[8]		0.4
Digger		8	0.4
Athene		3	0.2
Igri		4	0.1
Armelle		1	Trace
La Mesita		5	Trace
Livet		8?	Trace
Pirate		7	Trace
Astrix		2	0
Osiris		6	0

SED = 4.99
Mean of 4 replicates, final 2 assessment dates

REFERENCES

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

NET BLOTCH OF BARLEY

E R L JONES

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

All of the 1999 samples were collected from cv. Regina, on which increased virulence was detected in some field crops in 1998 and confirmed in 1998 adult plant glasshouse tests. Several of the 1999 infected leaf samples were collected from commercial crops or trial plots with low levels of infection but some, from different locations, showed levels of disease higher than seen prior to 1998. The majority of the current NIAB recommended winter and spring barleys were susceptible in glasshouse tests.

Twenty samples of net blotch were received in 1999 from a wide area of the country (Table 1).

Table 1 Geographic origins (county) of the 1999 net blotch samples

Location	Number of samples	Location	Number of samples
Yorks	7	Kent	1
Cleveland	1	Wilts	1
Lincs	4	Avon	1
Norfolk	2	Somerset	1
Suffolk	1	Pembs	1

All samples were from crops of cv. Regina, currently the most widely grown winter barley cultivar in the UK and which, prior to 1998, showed high levels of adult plant resistance. In that year two samples were received from cv. Regina which showed higher than expected levels of infection and this increased virulence was confirmed in adult plant glasshouse tests. Several of the crops from which the 1999 leaf samples were collected were infected at low levels (<2%) but some, from various regions of the country, showed 12% or more of flag leaf area infected.

The samples received from the 1999 survey were not tested individually on the standard set of seedling differential cultivars, but a mixture of selected isolates were inoculated onto seedlings and adult plants of a number of cultivars.

ADULT PLANT TESTS

Winter and spring barley cultivars were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included those cultivars 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 by spraying with a spore suspension of a mixture of isolates obtained from the following samples:

Isolate	Origin	Isolate	Origin
BNS-99-10	cv. Regina, York	BNS-99-15	cv. Regina, Pembrokeshire
BNS-99-13	cv. Regina, Somerset	BNS-99-16	cv. Regina, York

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 infection levels on the flag leaves and cultivars were classified on a 0-9 scale as being resistant (0-4) or susceptible (5-9).

SEEDLING TESTS

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

RESULTS

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

Winter barley

Table 2 shows that the majority of the winter barleys were susceptible. Those that were classified as resistant included cvs Vertige and Pearl which were resistant to different isolates in similar tests in 1998.

Cultivar Regina with a rating of 6 in 1999 tests was slightly more susceptible than in the previous year's tests when it was designated a rating of 5. In the two years prior to this cv. Regina had displayed high levels of resistance in adult plant tests, confirming its then NIAB disease rating as resistant. That the pathogen is carrying increased virulence to this cultivar appears to be confirmed by the 1999 tests as well as by the large number of survey samples from Regina received from diverse regions of the UK. Some of these samples were from crops/trial plots showing higher infection levels than seen prior to 1998.

Of the differential cultivars CI 9518 was susceptible.

Spring barley

These expressed a range of quantitative responses to the mixture of isolates with several being classified as resistant at the later growth stages (Table 3). Of the resistant cultivars, Riviera and Dandy have been susceptible to some of the isolates tested in previous years.

All of the spring differential cultivars were adult plant resistant with only the resistances of cvs CI 6311 and Proctor being ineffective at the seedling stage.

Although the majority of current NIAB recommended winter and spring barleys were susceptible, based on the reactions of the differential cultivars the test pathotypes only carry a narrow range of virulences (2,9,11).

REFERENCE

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

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

Cultivar [NIAB Rating]		Differential code number	*Adult plant reaction	†Seedling reaction
Melanie	[4]		7	4
Epic			7	-
Gleam	[4]		7	3
12431 VH1			7	4
Halcyon	[8]		6	3
Muscat	[6]		6	2
Heligan[8]			6	3
Hanna	[7]		6	4
Fanfare	[7]		6	4
Rifle			6	4
Regina	[7]		6	4
Intro	[7]		6	4
Antonia	[8]		6	3
Manitou	[4]		5	4
Angela	[5]		5	2
Jewel	[6]		5	3
CPBT B 23			5	4
Vanessa	[7]		5	3
Flute	[8]		4	3
Pearl	[5]		4	4
Vertige	[8]		2	3
CI 9518		10	7	3
Tenn. 61-119		11	3	2
Code 65		12	2	1

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

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

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

Cultivar	Differential Code number	*Adult plant reaction	†Seedling reaction
Century		8	3
Cooper		8	3
Prisma		7	3
Landlord		7	3
Chaser		7	3
Delibes		6	3
CSBA 4315-110		6	3
Static		6	3
Chalice		5	3
Optic		5	3
NFC 496-20		5	3
Riviera		3	3
Dandy		2	3
Chariot		2	3
Chime		1	3
Saloon		1	3
Decanter		1	4
C.I.5401	1	0	1
C.I.6311	2	0	3
C.I.9820	3	0	0
C.I.739	4	0	2
C.I.1243	5	2	2
C.I.4795	6	2	0
C.I.4502	7	0	2
C.I.4979	8	0	2
Proctor	9	0	3
C.I.9214	13	1	1

* area of flag leaf area infected on a 0-9 scale (mean of 2 plants)
Resistant: 0-4, Susceptible: 5-9
† seedling assessed on reaction type on a 0-4 scale
Resistant: 0-2, Susceptible: 3-4

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

M J ADAMS and C R COLLIER

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

Only 24 infected samples were received in 1999, 3 of which contained barley mild mosaic virus (BaMMV) alone, 19 had barley yellow mosaic virus (BaYMV) alone and 2 contained both viruses. This is the smallest number of samples since the survey began in 1987 and provided insufficient data to analyse cultivar responses. No new outbreaks of resistance-breaking BaYMV were reported.

INTRODUCTION

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

METHODS

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

RESULTS AND DISCUSSION

Only 24 positive samples were received in 1999 of which most (21 samples; 88%) contained BaYMV and 5 (21%) had BaMMV (Table 1). This is the smallest number of samples since the survey began in 1987 and provided insufficient data to make any sensible analysis of cultivar differences. No new outbreaks of resistance-breaking BaYMV were reported.

Table 1 Mosaic virus samples from 1999, classified by cultivar

Cultivar	BaMMV alone	BaYMV alone	Both viruses	Total samples
Fighter	0	1	0	1
Hanna	0	2	0	2
Intro	0	3	0	3
Lagune	0	1	0	1
Vertige	0	1	0	1
Feeding	0	8	0	8
Fanfare	1	0	0	1
Halcyon	1	0	0	1
Maris Otter	0	1	0	1
Pearl	0	1	0	1
Pipkin	1	1	1	3
Regina	0	2	0	2
Rifle	0	1	0	1
Malting	3	6	1	10
Unknown	0	5	1	6
TOTAL	3	19	2	24

REFERENCE

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

MILDEW OF OATS

E R L JONES

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

The widely virulent Race 7 which has remained at a low frequency over a number of years was identified in two of the seven isolates tested. Cultivar Banquo expressed adult plant resistance, the remainder of the NIAB Recommended List winter and spring oat cultivars displaying a range of quantitative susceptible responses to the isolates. The resistance of the differential cultivar Cc 6490 (OMR-4) was effective, although it showed high levels of a resistant reaction to one isolate to which it had been susceptible in previous seedling tests.

SEEDLING TESTS WITH 1999 ISOLATES

Nine samples of oat mildew, all from cv. Dula grown at trial sites were received in 1999. Isolates of *Blumeria graminis* DC Speer f.sp. *avenae*, formerly *Erysiphe graminis* DC f.sp. *avenae*, were cultured from seven of these and tested on seedlings of the differential cultivars (Table 1).

Table 1 Differential cultivars used for isolate testing

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

Results

The races identified and the geographic origins of the samples are given in Table 2.

Table 2 Geographic origins of oat mildew samples received in 1999 with races identified for isolates cultured from them

Isolate No. OMS-99-	Location	Race	OMV
1	Cambridge	5	1,2,3
2	Cambridge	5	1,2,3
3	Aberystwyth	5	1,2,3
4	Aberystwyth	5	1,2,3
5	Church Stretton	7	1,2,3,4
6	Aberdeen	-	-
7	Perth	5	1,2,3
8	Edinburgh	7	1,2,3,4
9	Lockerbie	-	-

Two virulence combinations were identified from the isolates. Race 5 (OMV-1,2,3), a relatively complex race which has been at a high frequency in the pathogen population in recent years, was identified in five of the isolates. The other race identified from the 1999 isolates was race 7 (OMV-1,2,3,4) which carries virulence to all of the differential cultivars. It was first identified in 1980 and has since remained at a generally low frequency.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF OAT MILDEW

Adult plant tests

Spring and winter oat cultivars 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 oats as well as the standard set of seedling differential cultivars. Two replicates of each cultivar were inoculated with one or other of the following isolates:

OMS-99-1	(OMV-1,2,3)	ex cv. Dula, Cambridge
OMS-99-8	(OMV-1,2,3,4)	ex cv. Dula, Edinburgh

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

Seedling tests

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

Results

Table 3 shows that all of the 1999 NIAB Recommended List winter and spring oat cultivars were seedling susceptible with only cv. Banquo expressing adult plant resistance. This resistance, effective against both isolates, had been overcome in similar tests in 1998 by isolates carrying the same virulence combinations as the 1999 pathotypes. A range of quantitative responses were expressed by the cultivars at the adult plant stage with cultivar rankings between isolates showing a similar pattern (Table 3).

Although the differential line Cc 6490 gave a resistant reaction type (1-2) to OMS-99-8 in 1999 tests, previous seedlings tests had shown it to be susceptible. In the 1999 tests, adult leaves showed a relatively high level of infection despite the low infection type. It may be that environmental variation between tests accounts for differences in reaction types.

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

Cultivar/Isolate [NIAB rating]		OMS-99-1 Race 5 (OMV-1,2,3)			OMS-99-8 Race 7 (OMV-1,2,3,4)		
		% Infection	Reaction type		% Infection	Reaction type	
			Adult	Seedling		Adult	Seedling
Spring oats							
Dula	[3]	80	S	(S)	60	S	(S)
Revisor	[4]	80	S	(S)	60	S	(S)
Valiant	[4]	60	S	(S)	40	S	(S)
Drummer	[6]	50	S	(S)	50	S	(S)
Manod	OMR-1	50	S	(S)	50	S	(S)
Kite	[7]	50	S	(S)	30	S	(S)
9065 Cn	OMR-3	50	S	(S)	35	S	(S)
Amigo	[6]	50	S	(S)	25	S	(S)
Winston	[8]	40	S	(S)	30	S	(S)
Cc 4146	OMR-2	40	S	(S)	30	S	(S)
Firth	[8]	40	S	(S)	30	S	(S)
Aberglen	[7]	30	S	(S)	15	S	(S)
Sailor	[6]	30	S	(S)	25	S	(S)
Bullion		20	S	(S)	20	S	(S)
Banquo	[7]	25	R	(S)	10	R	(S)
Cc 6490	ONR-4	0		(R)	35	R	(R)
Winter oats							
Grafton	[3]	80	S	(S)	50	S	(S)
Millenium	[5]	75	S	(S)	40	S	(S)
Viscount	[3]	70	S	(S)	40	S	(S)
Gerald	[4]	50	S	(S)	30	S	(S)
Aintree	[4]	50	S	(S)	25	S	(S)
Image	[4]	40	S	(S)	40	S	(S)
Kingfisher	[6]	50	S	(S)	15	S	(S)
Jalna	[6]	40	S	(S)	20	S	(S)
Lexicon	[7]	35	S	(S)	10	S	(S)
Birnam	[6]	30	S	(S)	5	S	(S)

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

CROWN RUST OF OATS

E R L JONES

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

A number of the isolates cultured from the 1999 leaf samples appeared to comprise a mixture of pathotypes which made it difficult to correctly assign them race numbers. The majority of the currently recommended spring and winter oats were highly susceptible in glasshouse tests. The resistance of the spring oat cv. Sailor was effective but those of cvs Millenium and Viscount were overcome by isolate CRS-99-4 tentatively assigned the international register race number 221.

GLASSHOUSE SEEDLING TESTS WITH 1999 ISOLATES

Nineteen of the 1999 crown rust samples were from spring oat cultivars with one sample being collected from a crop of winter oats. The geographic origins of the samples are given in Table 1.

Table 1 Geographic origins (county) of 1999 oat crown rust samples

Location	No. of samples
Yorkshire	11
Ceredigion	4
Cambridgeshire	1
Wiltshire	1
Shropshire	1
Lothian	1
Dumfries and Galloway	1

The eighteen isolates of *Puccinia coronata* cultured from the samples were tested on seedlings of the International Set of 10 differential cultivarss. Isolate:host interactions were recorded using standard conventions.

Results

Several of the isolates induced mixed responses on some of the differential cultivars suggesting they comprised a mixture of pathotypes. This sometimes made it difficult to classify the seedlings as susceptible or resistant but based on the predominant response of the cultivar the following races were identified from the 1999 samples.

Race	Susceptible differential cultivars	No. of isolates
251	Appler, Bond, Saia	13
272	Appler, Ukraine, Saia	2
238	Appler	1
205	Appler, Anthony, Bond, Saia	1
221	Appler, Anthony, Bond, Trispernia, Saia	1

Race 251 has been the most frequently identified race in recent seasons whilst races 272 and 205 have remained at a low frequency. The other two virulence combinations identified were assigned the international register race numbers 238 and 221. The identification of these two races in the UK pathogen population should, however, be treated with caution because of the mixed responses they induced on some of the differential cultivars.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF CROWN RUST

Adult plant tests

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

Isolate	Race	Origin
CRS-99-4	221	cv. Millenium, Wiltshire
CRS-99-10	272	cv. Revisor, Yorkshire

The plants were inoculated in a settling tower and then placed in dew simulation chambers at 15°C for 16 h prior to being incubated in the glasshouse at approximately 15°C for 16 days.

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

Seedling tests

Seedlings of the cultivars, grown to the second leaf stage, were inoculated with the same isolates under identical conditions to the adult plants. Seedling reactions were assessed on the first leaf and classified on the same 0-4 scale as the adult plants.

Results

These are given in Table 2. Cultivars are classified into groups on the basis of similarities in the pattern of their adult plant responses to the isolates.

Group 1: Cultivars susceptible except for cv. Banquo which gave a mixed, mainly resistant, response in seedling tests.

Group 2: Cultivar Millenium was resistant to the isolates against which it was tested in 1998 glasshouse tests and has a NIAB rating of 9 for crown rust resistance. In 1999 tests it was resistant to isolate CRS-99-10 (race 272) but showed high levels of a susceptible reaction to the more widely virulent race 221. Cultivar Viscount, also with a NIAB disease rating of 9, displayed a similar pattern of response.

Group 3: Adult and seedling leaves of cv. Sailor gave a resistant reaction type against both isolates listed. However, both isolates caused chlorosis of ca.60% of adult leaf area.

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

Cultivar/Isolate [NIAB rating]		Group	CRS-99-4 (Race 221)			CRS-99-10 (Race 272)		
Dula■	[5]	1	60	S	(S)	50	S	(S)
Kite■	[3]		60	S	(S)	40	S	(S)
Aberglen■	[3]		60	S	(S)	40	S	(S)
Winston■	[5]		60	S	(S)	35	S	(S)
Birnam	[7]		60	S	(S)	30	S	(S)
Image	[3]		50	S	(S)	50	S	(S)
Amigo■	[3]		50	S	(S)	50	S	(S)
Bullion■			50	S	(S)	50	S	(S)
Firth■	[5]		50	S	(S)	50	S	(S)
Gerald	[6]		50	S	(S)	40	S	(S)
Jalna	[5]		50	S	(S)	40	S	(S)
Lexicon	[7]		50	S	(S)	40	S	(S)
Grafton	[6]		50	S	(S)	40	S	(S)
Valiant■	[3]		50	S	(S)	40	S	(S)
Revisor■	[4]		50	S	(S)	40	S	(S)
Aintree	[4]		40	S	(S)	50	S	(S)
Kingfisher	[7]		40	S	(S)	50	S	(S)
Drummer■	[6]		40	S	(S)	40	S	(S)
Banquo			60	MS	(MR)	40	S	(S)
Millenium	[9]	2	50	S	(S)	50	MR	(MR)
Viscount	[9]		40	S	(S)	50	MR	(R)
Sailor■	[9]	3	60	R	(R)	60	R	(R)

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

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

MS = mixed susceptible; MR = mixed resistant

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

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 2000

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 1998 Annual Report.

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

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

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

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

REFERENCES

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

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

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

VARIETY DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF YELLOW RUST IN WHEAT, 2000

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

Choosing varieties to grow together

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

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

DG2
(WYR6,9)
Rialto

DG3
(WYR13)
Riband

DG7
(WYR CV)
Hereward
Shamrock
Spark

DG9
(WYR17)
Abbot
Brigadier
Buchan
Cockpit
Hussar
Reaper
Savannah

DG10
(WYR6,17)
Aardvark
Eclipse
Equinox
Genghis
Madrigal
Napier

DG0
*(**)*
Soissons

(S) = spring wheat

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

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

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

VARIETY DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY, 2000

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

Choosing varieties to grow together

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

DG1
Angela (W)
Pearl (W)
Vanessa (W)
Century (S)
Chalice (S)
Chariot (S)
Chime (S)
Dandy (S)
Decanter (S)
Derkado (S)
Hart (S)
Landlord (S)
Riviera (S)
Saloon (S)

DG5
Jewel (W)
Flute (W)

DG7
Cooper (S)
Delibes (S)
Tavern (S)

DG8
Manitou (W)

DG9
Optic (S)

DG10
Gleam (W)

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

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

Companion DG

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

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

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

NOTES