UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

OBJECTIVES

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

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

METHODS

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

- National Institute of Agricultural Botany, Cambridge - for mildew and yellow rust of wheat and barley.
- Institute of Grassland and Environmental Research, Aberystwyth - for brown rust of wheat and barley, Rhynchosporium and net blotch of barley, and mildew and crown rust of oats.

Other sampling methods such as static seedling nurseries are also used.

At each centre, virulence is measured by inoculating seedlings and/or adult plants with spores multiplied from the disease samples. Seedling tests are usually carried out under controlled environment conditions. Adult plant tests are carried out in the field, in polythene tunnels or in controlled environment rooms.

The rationale and uses of the Survey have been recently 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.

SUMMARY OF 1997 RESULTS

- **Mildew of wheat**

Virulence factors *2*, *4b*, *5*, *6*, *8* and *Ta2*, corresponding to the most common specific resistance genes in wheat cultivars, were present at frequencies of *c.* 100% in the wheat mildew population. The predominant pathotype, containing these six virulence genes, was present at a frequency of 42%. Most isolates could infect most current cultivars, except Cadenza and Spark. Specific resistance is not generally providing adequate control of the disease but there is good background resistance in wheat cultivars. No further shift towards morpholine insensitivity of isolates since 1996 was found.

- **Yellow rust of wheat**

Yellow rust was widespread in 1997, particularly in cultivars possessing the WYR 9,17 resistance factors. The frequency of the corresponding virulences WYV 9 and WYV 17 reached almost 100%. Virulence for WYR 6,9,17 was confirmed in an adult plant polythene tunnel test of an isolate collected in 1996. This virulence overcame the resistance of the cultivars Madrigal, Equinox and Lynx.

- **Brown rust of wheat**

Seedling tests identified virulence to WBR-7 in two isolates. These isolates were the only ones to infect cv. Chablis and the Thatcher Lr3 lines. Adult plant tests in controlled environments confirmed one of these isolates as carrying virulence to cvs Chablis, Savannah and Chaucer which have previously shown high levels of resistance in field nurseries at IGER. The resistances of many of the currently grown wheat cultivars remained effective to the isolates against which they were tested in field isolation nurseries.

- **Mildew of barley**

Virulence factors corresponding to resistance factors in current barley cultivars were recorded at high levels similar to previous years. The population remains complex with isolates carrying up to 13 virulence factors. There was no dominant pathotype, the commonest occurring in only 8% of the samples. The only effective specific resistance continues to be *mlo*, although many winter cultivars possess good levels of non-specific resistance.

Virulence frequencies in Northern Ireland were similar to 1996: *Vla,Val3* remained at a relatively high level despite a lack of selection. Virulence frequency means in 1990-96 correlated well with British values but there was poor correlation in trends of individual frequencies.

- **Yellow rust of barley**

No samples were received in 1997. Seedling and adult plant tests provided more information on the susceptibility/resistance of current cultivars. Susceptible cultivars will comprise approximately 35% of the winter and 13% of the spring barley acreage in 1998, thus greatly increasing the risk of this disease returning to barley crops. Fortunately, resistant cultivars are available, but variety diversification is needed to reduce selection pressure on the pathogen population.

- **Brown rust of barley**

Isolates cultured from the 1997 samples carried virulence, in various combinations, to all of the differential cultivars with the exception of BBR-7 virulence which has not been identified in the UK. A number of spring barleys, mainly derivatives of cv. Chariot, which displayed higher levels of brown rust than expected at some sites in 1996, were resistant in adult plant field nurseries; the high levels of disease displayed were mainly of a resistant infection type. Glasshouse tests identified the majority of the currently recommended NIAB spring barleys and some of the winter barleys as carrying effective adult plant resistance.

- ***Rhynchosporium* of barley**

1997 isolates were generally less widely virulent than in recent years, with virulence to a number of the differential cultivars at a reduced frequency. Cultivar Digger, which has shown high levels of resistance in seedling and adult plant tests over a number of years to nearly all isolates and carries a different resistance to other differential cultivars, was added to the differential set. The corresponding virulence, BRV-8, was identified in one isolate. Glasshouse tests confirmed that a number of winter barleys carry a specific resistance (BRR-2). Of the spring barleys, which were generally susceptible, cv. Ferment is thought to carry BRR-1 and cv. Livet BRR-8.

- **Net blotch of barley**

Isolates obtained from the large number of samples of this disease, which was at a high incidence in 1997, were identified in seedling tests as carrying virulences, in various combinations, to all of the differential cultivars. The majority of the currently recommended winter barley cultivars were susceptible as seedlings and adult plants to a specific isolate of the pathogen under glasshouse conditions.

- **Soilborne mosaic viruses of barley**

127 infected samples were received in 1997: 47% contained barley mild mosaic virus (BaMMV) and 67% barley yellow mosaic virus (BaYMV). The most frequent combinations were BaYMV on Fighter and Intro (9 samples of each) and BaMMV on Puffin (11 samples). Six new outbreaks of resistance-breaking BaYMV were reported, bringing the UK total to 23.

- **Mildew of oats**

Race 5 (OMV-1,2,3) was identified from all the isolates cultured from the 1997 samples. Glasshouse tests identified the winter oat cvs Jalna, Emperor, Solva, Gerald and Lexicon and the spring oat cv. Aberglen as carrying resistances effective at the adult plant stage to the isolate (OMV-1,2,3) against which they were tested.

- **Crown rust of oats**

Two races, 251 and 289, were identified from the leaf samples of oat crown rust. Of the current NIAB recommended spring and winter oats, cvs Sailor and Piper expressed resistance in seedling tests to these pathotypes.

CSL/ADAS WINTER WHEAT & WINTER BARLEY DISEASE SURVEYS, 1997

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WINTER WHEAT

Summary

In 1997, 367 randomly selected fields of winter wheat were sampled and assessed for the incidence and severity of disease in a survey undertaken jointly by CSL and ADAS. The fields were identified using a farm list stratified by the area of wheat grown in each region. Samples were taken in July when crops were at the milky-ripe growth stage (GS 73-75). Mildew affected 0.2% area of leaf 2, the lowest level since 1995, which was the lowest since the survey began in 1970. *Septoria tritici*, at 3.1% area of the second leaf, was at a higher level than in 1996 (2.1%). *Septoria tritici* was again the most severe foliar disease. *Septoria nodorum* was present at 0.3% area of the second leaf and at trace levels on the ears. In no region did the level of mildew exceed 0.3% of the area of leaf 2. Brown rust was recorded only at trace levels in the North and East on leaf 2. Yellow rust was recorded on the ears at trace levels for the first time since 1992 and affected 0.1% of leaf 1, the highest levels since 1990. Levels of eyespot, at 14.2% stems affected with moderate and severe symptoms, were higher than in any survey since 1988 (15.1%). Sharp eyespot levels showed an increase to 4.2% stems affected by moderate and severe symptoms compared with 2.5 % stems in 1996 and 4.6% in 1995. Fusarium diseases affected 28.9% of stem bases. Fusarium ear blight and glume spot affected 8.6% of ears, the highest level since 1993. Take-all was present in 18% of crops and patches recorded in 2.8% of crops. Symptoms of BYDV were recorded in 7% of crops, levels similar to 1996.

Riband was the most commonly sampled cultivar at 22% of crops, a position it held for the seventh successive year, followed by Brigadier (21%) and Consort (11%). Buster carried the highest levels of mildew (0.4% area of leaf 2), Hussar the highest levels of *S. tritici* (4.5% area of leaf 2), Hunter the highest levels of *S. nodorum* (1.2% area of leaf 2) and Rialto the highest levels of yellow rust (0.2% area leaf 2). Levels of eyespot were lowest following grass and sharp eyespot following wheat. Moderate and severe levels of Fusarium stem base diseases were highest following other cereals. Take-all levels were lowest following pulse or potatoes, but most severe following set-aside. Monoculture had little effect on levels of either Fusarium or sharp eyespot, but eyespot levels tended to be highest following a second or third wheat and take-all most severe in a second wheat. *S. tritici* was most severe in crops drilled in mid-October and mildew in crops drilled after October. Eyespot and Fusarium were most severe in crops drilled before October and sharp eyespot most severe in crops drilled in mid-October. Take-all was least severe in crops drilled after the end of October. Fungicide sprays were used on 97% of the crops sampled, with 83% receiving two or more treatments. The most popular regime, applied to 23%

of crops, was a two-spray programme with the first spray applied at GS 31 followed by a second spray at GS 39.

Twenty eight per cent of crops received a three-spray programme. The most popular being the first spray at GS 31, followed by GS 39 and 59, applied to 19% of crops. Crops received on average 2.2 fungicide spray applications, the same as 1995 and 1996. Seventy nine per cent of crops were grown from certified seed with 98% of crops sown with fungicide treated seed. A total of 304 insecticide products were applied, 66% in the autumn, 20% from the spring to GS 37 and 14% from GS 38 to 75.

Table 1 National foliar disease levels (per cent area affected)

	Leaf 1	Leaf 2	Ear
Mildew	tr	0.2	0.2
S. tritici	0.7	3.1	-
S. nodorum	tr	0.3	tr
Yellow rust	0.1	tr	tr
Brown rust	tr	tr	-
Didymella	0.0	tr	-
Cephalosporium	0.0	0.0	-
Tan spot	0.0	0.0	-
Insect damage	0.7	0.4	-
Green leaf area	93.0	84.6	-

Table 2 National stem base disease levels (per cent stems affected)

	Slight	Moderate	Severe
Eyespot	16.8	13.6	0.6
Sharp eyespot	3.5	3.8	0.4
Nodal *Fusarium*	14.1	10.2	tr
Internodal *Fusarium*	6.9	2.7	0.2
All *Fusarium*	17.0	11.7	0.2

Table 3 National Fusarium levels on the ears.

Year	% Samples affected		% Ears affected	
	Ear blight	Glume spot	Ear blight	Glume spot
1992	17.6	35.8	1.8	3.9
1993	17.1	49.0	1.9	8.3
1994	5.2	24.6	0.3	2.0
1995	2.0	11.3	0.1	0.7
1996	1.9	10.6	0.1	0.7
1997	21.8	62.7	1.6	7.0

Table 4 National take-all levels

	Take-all category					Total with
	0	1	2	3	4	take-all
Number of crops (1996)	304	31	10	2	1	44
Percent of total (1996)	87.4	8.9	2.9	0.6	0.3	12.6
Number of crops (1997)	287	55	4	2	4	65
Percent of total (1997)	81.5	15.6	1.1	0.6	1.1	18.5

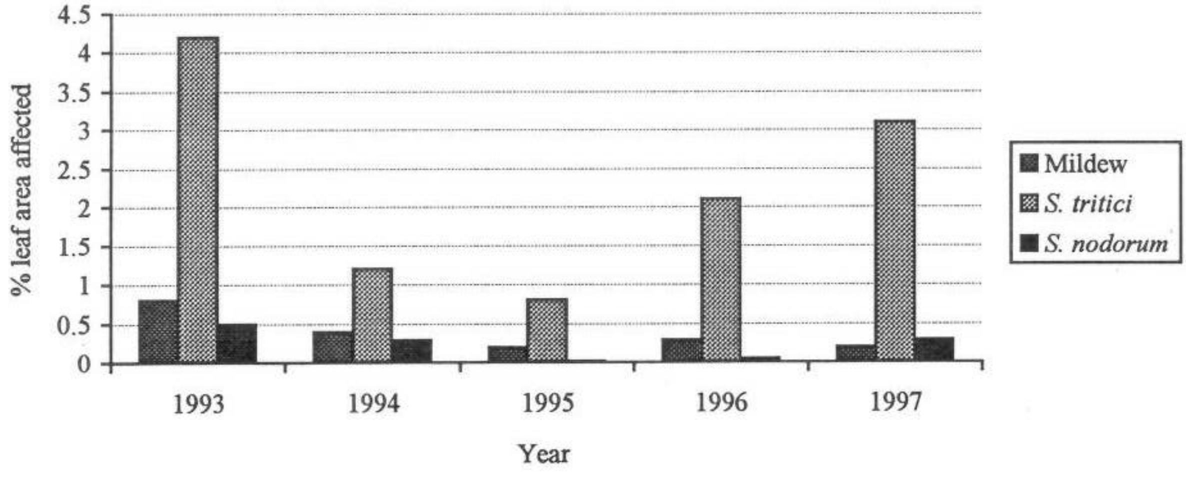
Table 5 Regional foliar disease levels (% area leaf 2)

Region	No of Samples	Mildew	*Septoria tritici*	*Septoria nodorum*	Yellow rust	Brown rust	*Didy -mella*	Tan spot	*Cephalo -sporium*
NO(N)	30	0.1	1.7	0.4	tr	0.0	0.0	0.0	0.0
NO(L)	47	0.3	2.0	0.2	tr	tr	0.0	0.0	0.0
M & W	68	0.2	2.8	0.6	tr	0.0	0.0	0.0	0.0
EAST	174	0.2	2.9	0.2	tr	tr	tr	0.0	0.0
SE(W)	23	0.2	6.4	0.1	tr	0.0	0.0	0.0	0.0
SE(R)	36	0.1	1.5	tr	0.0	0.0	0.0	0.0	0.0
SW(B)	35	0.3	4.6	0.3	0.0	0.0	tr	0.0	0.0
SW(S)	6	0.3	10.0	0.9	0.0	0.0	0.0	0.0	0.0
WALES	32	0.3	6.7	0.1	0.1	tr	tr	0.0	0.0
National (stratified)	367	0.2	3.1	0.3	tr	tr	tr	0.0	0.0

Severity of foliar and stem disease

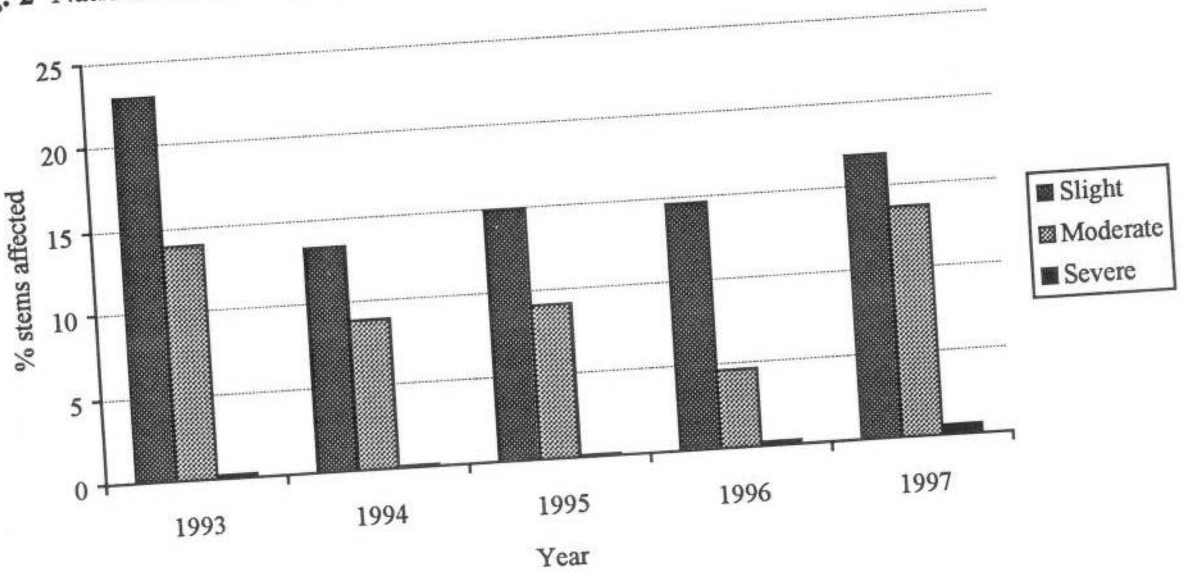
Three diseases, mildew, *Septoria nodorum* and *S. tritici* were present at levels at more than 0.1% area leaf 2 affected (Fig. 1). Yellow rust and *Didymella* were present at only trace levels. Total foliar disease was higher than in the previous three years.

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



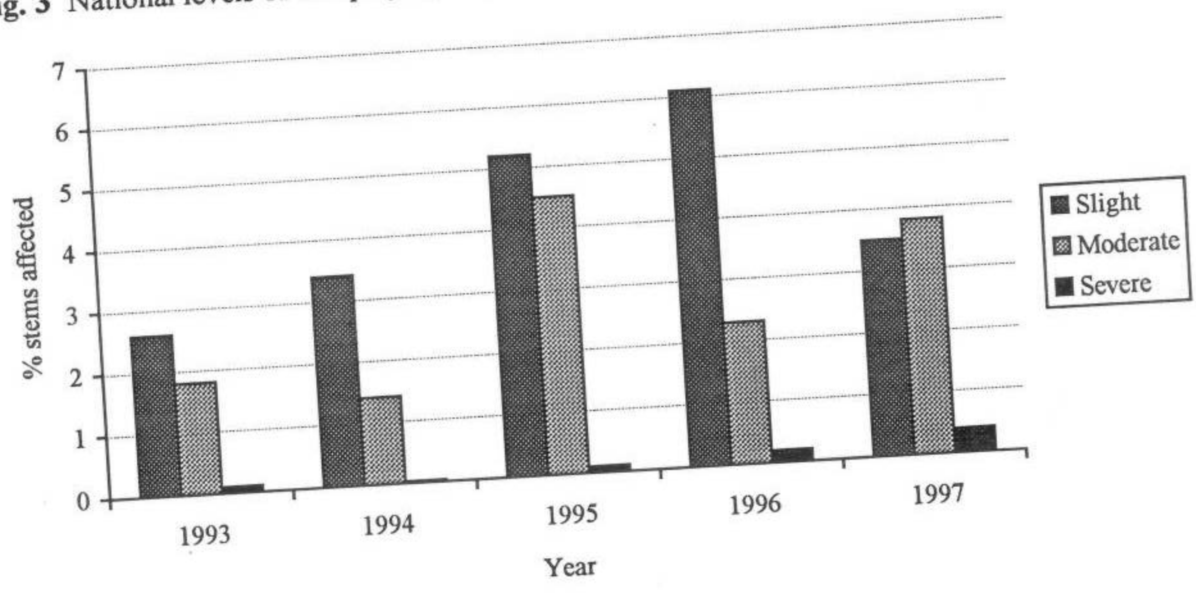
Eyespot was present in 89% of crops. Moderate and severe infections were higher than the previous three years (Fig. 2).

Fig. 2 National levels of eyespot (mean % stems affected)



Sharp eyespot was present in 60% of crops but moderate and severe levels were higher compared with 1996 (Fig. 3).

Fig. 3 National levels of sharp eyespot (mean % stems affected)



Regional disease incidence and severity

The dominant disease was *S. tritici*, with the highest levels occurring in the South West (Starcross). The highest levels of *S. nodorum* were also recorded in the South West (Starcross) The lowest levels of *S. tritici* were recorded in the South East (Reading). Mildew was recorded

WINTER BARLEY

Summary

In 1997, 377 randomly selected fields of winter barley were sampled in a disease survey undertaken jointly by CSL and ADAS. The fields were identified using a farm list stratified by the area of barley grown in each region, and samples taken in June and early July when crops were at the watery-ripe to early-milk stage (GS 71-73). Net blotch and Rhynchosporium were the most common of the foliar diseases, each being found in 82% and 78% of crops, respectively. Net blotch was the most severe, affecting 2.3% of the area of the second leaf. Rhynchosporium affected 1.8% and mildew 0.5% area of leaf 2, respectively. Mildew levels were the lowest since the survey began in 1981. Brown rust was found in 35% of crops but only at low levels (0.6% area of leaf 2). Yellow rust was found in samples from the North and South East but was present only at trace levels. Septoria was at trace levels in all regions except the South East (Wye) where it was not recorded. Net blotch was most severe in the South East (Wye) (4.7% area leaf 2) and the East (3.4% area leaf 2). Eyespot was recorded in 87% of crops, the same as in 1996. Eyespot was more severe, with 9.1% of stems affected by moderate and severe symptoms compared to 6.6% in 1996. Sharp eyespot was recorded more frequently than in 1996, affecting 35% of crops sampled and with moderate and severe symptoms affecting 1.1% of stems. Fusarium symptoms were found in 92% of crops, with nodal Fusarium found at moderate levels on 9.0% of stems.

Intro, Fighter and Pastoral were the most popular cultivars grown, accounting for 17%, 15% and 11% crops, respectively. The highest levels of net blotch was found on Melanie at 14.2% area of leaf 2 (NIAB rating 5). The highest level of Rhynchosporium was recorded on Fighter at 4.1% area of leaf 2 (NIAB rating 6). Mildew was most severe on Regina (1.5% area of leaf 2, NIAB rating 3). Net blotch and eyespot were more severe on crops drilled before 24 September. Eyespot was most damaging in crops following a cereal. Fungicide sprays were used on 95% of crops. Eight per cent of crops were treated with a fungicide before the end of tillering, 76% at or around GS 31 and 63% at or after flag leaf emergence. Forty per cent of crops received a single spray, mainly at GS 31, and 48% were sprayed twice, mainly at GS 31 with a second spray at or after GS 37. Seven per cent of crops received three or more fungicide sprays. The most commonly applied products were Opus (69 applications), Corbel (65 applications), Punch C (61 applications) and Genie (51 applications). Eighty three per cent of crops in the survey were grown from certified seed, and 97% of all crops were grown from fungicide treated seed.

Table 1 National foliar disease levels (per cent leaf area affected)

	Leaf 1	Leaf 2
Mildew	0.1	0.5
Brown rust	0.3	0.6
Net blotch	0.7	2.3
Rhynchosporium	0.9	1.8
Septoria	tr	tr
Selenophoma	tr	tr
Yellow rust	tr	tr
Insect damage	0.3	0.2
Green leaf area	88.7	77.7

Table 2 National stem base disease levels (per cent stems affected)

	Slight	Moderate	Severe
Eyespot	16.1	8.7	0.4
Sharp eyespot	1.9	1.0	0.1
Nodal *Fusarium*	13.5	9.0	0.1
Internodal *Fusarium*	5.0	1.5	0.1
All *Fusarium*	16.3	10.1	0.1

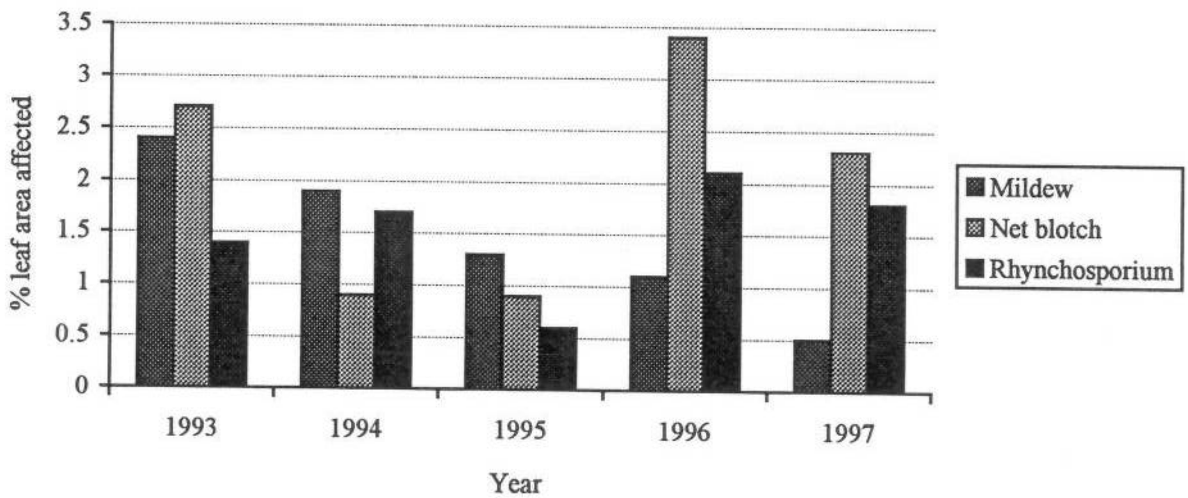
Table 3 Regional foliar disease levels. Second leaf (per cent leaf area affected)

Region	No. of samples	Mildew	Brown rust	Net blotch	*Rhyncho -sporium*	*Septoria*	*Seleno -phoma*	Yellow rust
NO(N)	44	0.8	0.6	2.0	1.4	tr	0.0	tr
NO(L)	48	0.4	1.4	1.3	0.3	tr	0.0	0.0
M & W	79	0.6	tr	0.6	2.8	tr	tr	0.0
EAST	117	0.3	0.4	3.4	0.9	tr	tr	0.0
SE(W)	31	0.8	1.1	4.7	1.1	0.0	0.0	0.0
SE(R)	37	0.6	0.1	1.7	2.6	tr	0.0	0.0
SW(B)	37	0.3	0.1	2.3	3.6	tr	0.0	0.0
SW(S)	25	0.2	1.5	2.4	3.4	tr	0.0	0.0
WALES	31	0.7	1.5	0.5	5.4	0.1	0.0	0.0
National (stratified)	377	0.5	0.6	2.3	1.8	tr	tr	tr

Severity of foliar and stem disease

Four diseases, mildew, net blotch, Rhynchosporium and brown rust reached levels of more than 0.1% area leaf 2 affected. Net blotch was the most severe disease at 2.3%. Mildew severity, at 0.5% area of leaf 2, was the lowest since the survey began in 1981 (Fig. 1).

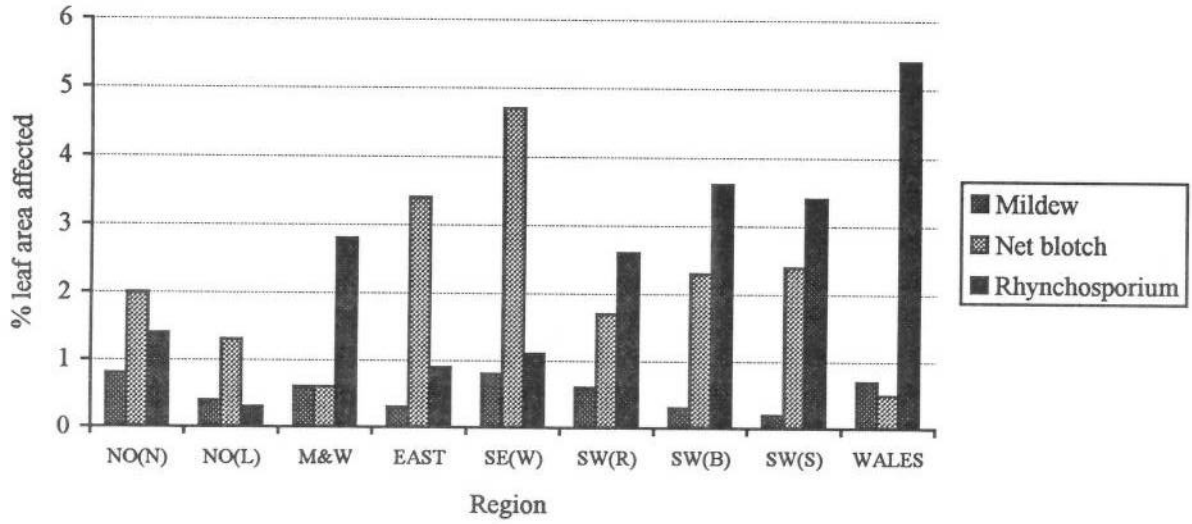
Fig. 1 National foliar disease levels (mean % area leaf 2 affected)



Regional disease severity

Levels of mildew were low everywhere, net blotch was most severe in the South East (Wye) (4.7% area leaf 2) and the East (3.4% area leaf 2) and Rhynchosporium in the South West and Wales (Fig.2).

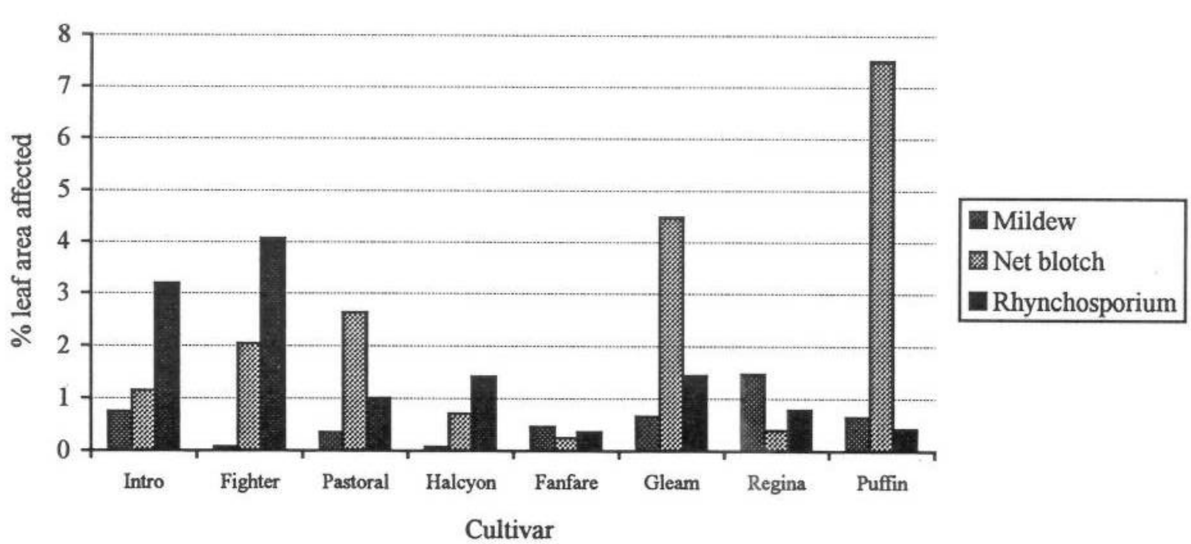
Fig. 2 Regional foliar diseases levels (mean % area leaf 2), 1997



Effect of cultivar on disease severity

Intro, Fighter and Pastoral were the most popular cultivars grown, accounting for 17%, 15% and 11% crops, respectively. The highest levels of net blotch were found on Melanie at 14.2% area of leaf 2 (NIAB rating 5), next was Puffin with 7.5% (NIAB rating 4). The highest level of Rhynchosporium was recorded on Fighter at 4.1% area of leaf 2 (NIAB rating 6). Mildew was most severe on Regina (1.5% area of leaf 2, NIAB rating 3).

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



Key to regions

Code	Region	County
NO(N)	North	Cleveland, Cumbria, Northumberland, Durham, N. Yorks (Northallerton), Tyne & Wear
NO(L)	North	Humberside, N. Yorks (Harrogate), S. Yorks, W. Yorks (Leeds)
M&W	West Mids & East Mids	Cheshire, Derbyshire, Notts, Leics, Hereford & Worcester, Gr Manchester, Lancs., Merseyside, Shropshire, Staffordshire, Warwickshire, West Midlands.
EAST	East	Bedfordshire, Cambridgeshire Northants, Essex, Hertfordshire, Lincolnshire, Norfolk, Suffolk, Gr London (Eastern)
SE(W)	South-East	Kent, Surrey, E. Sussex W. Sussex, Gr London (SE)
SE(R)	South-East	Berkshire, Buckinghamshire Hampshire, Oxfordshire
SW(B)	South-West	Avon, Dorset, Gloucestershire, Somerset, Wiltshire
SW(S)	South-West	Cornwall, Devon
Wales	Wales	All Welsh Counties

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MILDEW OF WHEAT

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Virulence factors *2*, *4b*, *5*, *6*, *8* and *Ta2*, corresponding to the most commonly deployed specific resistance genes, were present at frequencies of *c*. 100% in the wheat mildew population. The predominant pathotype, containing these six virulence genes, was present at a frequency of 42% and could infect most current cultivars, except Cadenza and Spark. The mildew population continues to show decreasing heterogeneity. Thus, specific resistance is not generally providing adequate control of the disease, necessitating heavy reliance on partial resistance and use of fungicides. No further shift towards morpholine insensitivity of isolates since 1996 was found.

INTRODUCTION

Mildew (*Blumeria* (syn. *Erysiphe*) *graminis* f.sp. *tritici*) in winter wheat survived the winter well and high levels of infection were present in susceptible cultivars by the spring of 1997. Subsequent mild, dry conditions led to further spread to less susceptible cultivars, but wet weather in the May/June period tended to arrest disease development. Consequently, mildew was less common in spring wheat and no samples were received.

METHODS

A total of 265 samples of wheat mildew were received in 1997, mostly from trial plots. Single colony isolates were successfully cultured from 159 samples. The isolates were taken from infected leaves of the following cultivars:

Winter cultivars	No. of isolates		No. of isolates		No. of isolates
Cadenza	43	Consort	9	Hussar	7
Hunter	44	Equinox	9	Apollo	6
Crofter	12	Harrier	9	Beaufort	6
Drake	11	Soissons	9	Brigadier	6
Maverick	11	Abbot	8	Dynamo	6
Savannah	11	Blaze	8	Haven	6
Cantata	10	Charger	8	Hereward	6
Chaucer	10	Encore	8	Rialto	5
Madrigal	10	Reaper	8	Mercia	4
Riband	10	Buster	7	Slejpner	4
Spark	10	Caxton	7		
Total	**328**				

The samples were collected from the following locations:

	No. of isolates		No. of isolates
NIAB, Cambridge	113	Bridgets, Hants.	19
Morley, Norfolk	49	Cockle Park, Northumb.	15
Headley Hall, N Yorks.	49	Rosemaund, Hereford & Worcs.	8
Wye, Kent	37	Boxworth, Cambs.	6
Long Sutton, Lincs.	31	High Mowthorpe, N Yorks	1
Total	**328**		

72 samples failed to produce viable conidia, and a further 32 isolates taken were not tested. Isolates were inoculated onto detached leaf segments of differential cultivars, using a settling tower, and assessed for virulence on a 0-4 scale for infection type (Moseman *et al*, 1965). The differential cultivars used to test the isolates for virulence factors are shown in Table 1.

Table 1 Differential cultivars used to determine virulence factors in isolates of wheat mildew in 1997.

Differential cultivar	European code	Resistance genes	WMR group
Cerco	none	None	0
Galahad	Pm2	*Pm2*	2
Chul	Pm3b	*Pm3b*	3b
Armada	Pm4b	*Pm4b*	4
Flanders	pm5	*pm5*	5
Brimstone	Pm2, Pm6	*Pm2, Pm6*	2,6
Clement	Pm8	*Pm8*	7
Amigo	Pm17	*Pm17*	10
Maris Dove	Mld	*Mld*	9
Brock	Pm2, MlTa2	*Pm2*, Unknown	2,'Talent'
Mercia	pm5, MlTa2	*pm5*, Unknown	5,'Talent'
Tonic	MlTo	Unknown	p
Broom	Pm3d	*Pm3d*	3d
Sicco	pm5, MlSi2	*pm5*, Unknown	5,r
Wembley	MlSo	Unknown	'Sona'
Axona	MlAx	Unknown	'Axona'
Cadenza	MlAx (Mld, Pm3d?)	Unknown	'Axona' (+9, q?)

RESULTS

Virulence frequencies

Virulence frequencies of *V4b*, *5*, *6* and *8* again showed slight increases compared with the previous year (Clarkson & Slater, 1997) and are almost fixed in the mildew population, as is

V2 (Table 2). The frequency of *V5,Si2* showed a decline from 1996 levels. The large number of samples of Cadenza tested again resulted in *Vd*, *3d* and *Ax* being at similar, or slightly lower, levels compared with 1996. Virulence for *Pm3b* and *17* appears to be relatively static at 4% and 16% respectively: selection for these probably originates from breeding programmes as no current wheat cultivars possess these resistance genes.

Table 2 also shows the 1997 areas of resistance genes corresponding to the specific virulence factors. It is apparent that cultivars with *Pm2*, *4b*, *6* and *8* account for most of the acreage: all these have corresponding virulence frequencies of *c*. 100% and are thus ineffective for mildew control.

Table 2 Frequency of wheat mildew virulence factors in isolates from infected leaves, 1992-1997, and 1997 areas of cultivars with the corresponding resistance.

	Frequency of virulence factors (%)						
Virulence factor	1992	1993	1994	1995	1996	1997	Area
2	99	98	99	99	100	100	32
3b	-	-	-	4	3	4	0
4b	73	79	84	88	93	98	36
5	90	95	92	92	93	95	1
6	76	78	80	89	96	99	52
8	86	93	93	95	96	98	11
17	-	-	-	10	15	16	0
d	27	15	20	19	33	26	0
2,Ta2	60	80	82	85	92	93	1
To	24	18	24	18	29	29	1
3d	31	20	27	21	32	30	0
5,Si2	32	39	26	22	32	21	0
So	23	22	21	10	15	15	0
Ax	17	10	14	11	24	20	1
Number of isolates tested	194	356	347	265	313	328	

The 1997 frequencies of the most common pathotypes of wheat mildew are given in Table 3. The total number of pathotypes recorded was considerably lower than in 1996, continuing the trend of reduced heterogeneity in the population (Clarkson & Slater, 1996). The dominant pathotype *V2,4b,5,6,8,Ta2* accounted for 42% of the pathotype population, maintaining the upward trend of the past 5 years. This corresponds well with the resistance genes present in current NIAB Recommended List cultivars. The frequency of pathotype *2,4b,5,6,8,d,Ta2,To,3d,Ax* showed an increase over 1996 levels, again probably reflecting the numbers of isolates from Cadenza tested.

Table 3 Frequencies of the most commonly identified pathotypes in 1992 - 1997 as defined by the differential cultivars listed in Table 1.

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

* All pathotypes also carry V2

Table 4 shows the numbers of virulence factors in the isolates of wheat mildew sampled; the dominant pathotype carries six virulence factors. This situation differs greatly from that of the **barley** mildew population, which is more heterogeneous than that of wheat and contains large numbers of complex pathotypes (Slater & Clarkson, 1997).

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

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

* Includes all virulences in Table 1 except *Pm17* (Amigo)

In Table 5, the proportion of wheat mildew isolates tested which can attack NIAB Recommended List cultivars and others is shown. It is noteworthy that almost all isolates can infect most cultivars, with the exception of Cadenza and Spark. The proportion of isolates infecting the latter cultivars was similar to that in 1996.

Table 5 The proportion of mildew isolates tested in 1997 able to infect winter wheat cultivars in Recommended List trials. (1998 Recommended List cultivars in **bold**)

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Caxton	100	**Madrigal**	98
Charger	100	Maverick	98
Hereward	100	**Riband**	98
Rialto	100	**Beaufort**	97
Abbot	99	**Equinox**	97
Buster	99	**Brigadier**	95
Reaper	99	Crofter	95
Blaze	98	**Harrier**	95
Cantata	98	**Hussar**	98
Chaucer	98	**Savannah**	95
Consort	98	**Spark**	28
Drake	98	**Cadenza**	20

Resistance Factors in New Cultivars

The specific resistance factors in winter wheat cultivars are shown in Table 6. No new genes or gene combinations were identified in new or existing cultivars. Spark has been shown to carry *MlTo* and Cadenza is thought to possess *MlAx* and, possibly, *Mld* and *Pm3d* also. It is still unclear which factors are present in cultivar Soissons.

Table 6 Specific mildew resistance factors of winter wheat cultivars. (1998 Recommended List cultivars in **bold**)

None	*Pm2,Pm4b*	*Pm2,Pm4b,Pm8*	*Pm5,MlTa2*
Charger	Maverick	Crofter	Mercia
Caxton		**Savannah**	
Hereward	*Pm2,6*		*MlTo*
Rialto	**Abbot**	*Pm6,Pm8*	**Spark**
	Buster	**Beaufort**	
Pm6		**Equinox**	*MlAx (Mld,Pm3d?)*
Reaper	*Pm2,4b,6*	**Madrigal**	**Cadenza**
	Cantata		
Pm8	Chaucer	*Pm4b,Pm6,Pm8 (Pm2?)*	*Unknown*
Blaze	**Consort**	**Brigadier**	**Soissons**
Drake	**Riband**	**Hussar**	
		Harrier	

Fungicide Sensitivity Tests

No isolates from the 1997 survey were tested for fungicide resistance, but **92** isolates of *B. graminis* f. sp. *tritici* were screened for fenpropimorph resistance in another study. Here, samples were taken from trial plots of cvs Cadenza and Hunter sprayed with morpholine fungicides ("half-rate" programme) at GS 32, 39 and 59 at Cambridge and Cockle Park, and from nearby untreated plots. Isolates were tested for fenpropimorph resistance and EC_{50}s determined; sensitive and insensitive control isolates were included for comparison (Table 7). Resistance factors (RF) were calculated as follows: RF = isolate EC_{50}/mean EC_{50} of sensitive controls.

Table 7 Sensitivity of wheat mildew isolates to fenpropimorph, 1997

Cultivar	No. of isolates	Mean EC50	Mean RF*
Cadenza	45	27.6	5.7
Hunter	47	34.4	7.3
Sensitive controls	2	5.2	(1.0)
Insensitive controls	3	34.2	6.7

* Resistance Factor (see text)

The results were similar to those found in 1996 for these two cultivars; the EC_{50}s of the control isolates were also of the same order (Clarkson & Slater, 1997). Thus, there is no evidence of a shift towards insensitivity to morpholines since 1996.

As in 1996, isolates from untreated plots were more insensitive than those from plots which had received morpholine treatments, particularly in Hunter, although this effect became progressively less marked through the season at Cambridge. It is suggested that the untreated plots carry a more heterogeneous mildew population than those treated with fungicide, although there may be a shift towards greater insensitivity in the latter as the number of treatments increases.

CONCLUSIONS

Most of the common virulence factors were present at levels similar to, or slightly higher than, those found in 1996. Virulence factors *2*, *4b*, *5*, *6*, *8* and *Ta2* were all at, or near, 100% frequency in the wheat mildew pathogen population, associated with high acreages of wheat cultivars with the corresponding host resistance factors. Accordingly, the predominant pathotype, containing the above six genes, was found at a frequency of 42%. The gene combination *5,Si2* was found at a lower frequency in 1997, while *3b* and *17* remained at 1996 levels. The population continues to exhibit a trend towards reduced heterogeneity.

Nearly all isolates were able to infect all NIAB Recommended List cultivars, with the exception of Cadenza and Spark.

From the virulence survey data, it is clear that most specific resistance factors are not providing any control of wheat mildew and thus heavy reliance is being placed on the good partial resistance of cultivars and on fungicide usage for disease control.

There was no evidence of a further shift towards morpholine insensitivity in wheat mildew isolates since 1996.

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YELLOW RUST OF WHEAT

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Yellow rust was widespread in 1997, particularly in cultivars possessing the WYR 9,17 resistance factors. The frequency of the corresponding virulences WYV 9 and WYV 17 reached almost 100%. Virulence for WYR 6,9,17 was confirmed in an adult plant polythene tunnel test of an isolate collected in 1996. This virulence overcame the resistance of the cultivars Madrigal, Equinox and Lynx.

1997 VIRULENCE SURVEY

Yellow rust was widespread in 1997, particularly in the highly susceptible cultivar Brigadier (WYR 9,17), which accounted for around 20% of the winter wheat acreage (Table 1). The cultivars Reaper and Hussar, with the same specific resistance as Brigadier, occupied a further 15% of the acreage.

Table 1 Popularity of winter wheat cultivars, 1997
(from seed certification statistics for England and Wales)

Cultivar	WYR Factors	NIAB Resistance Rating (1-9)	% acreage
Riband	13	6	23.1
Brigadier	9,17	1	19.6
Reaper	9,17	4	8.6
Hussar	9,17	5	6.2
Consort	CV	8	10.8
Hereward	CV	6	7.7
Rialto	6,9	6	4.3
Soissons	3	7	3.2
Hunter	6,9 + APR	9	3.0
Buster	R	9	2.9
Charger	? 6 + APR	8	1.6
Others	-	-	9.0

138 isolates of *Puccinia striiformis* were tested, the highest number since the epidemic in 1989. Isolates came from 29 cultivars (Table 2), mostly from Brigadier and other WYR 17 cultivars. The majority originated from high risk areas of the country (Table 3), i.e. Lincolnshire, Cambridgeshire and Norfolk, but a significant number were received from outside this area,

including the Midlands and south-west. No isolates were received from Scotland, probably due to the low acreage of Brigadier grown north of the border.

Table 2 1997 isolates - cultivars of origin

Variety	WYR factors	% isolates
Brigadier	9,17	34.1
Hussar	9,17	12.3
Reaper	9,17	6.5
Riband	13	6.5
Savannah	9,17	5.8
Blaze	9,17	5.1
Harrier	9,17	3.6
Maverick	9,17	2.9
Drake	9,17	2.9
20 others	-	20.3

Table 3 1997 isolates - counties of origin

County	% isolates	County	% isolates
Lincs	25.4	Leics	1.5
Cambs	15.2	Hants	1.5
Norfolk	14.4	Warwickshire	1.5
Essex	7.2	Worcs	1.5
Suffolk	5.8	Northamptonshire	0.7
Yorkshire	5.8	Notts	0.7
Gloucs	4.3	Berks	0.7
Kent	3.6	Sussex	0.7
Oxfordshire	2.9	Devon	0.7
W. Midlands	2.2	Somerset	0.7
Northumberland	2.2	Shropshire	0.7

Isolates were tested for virulence on seedlings of the differential cultivars listed in Table 4, using the methods described by Priestley, Bayles and Thomas, 1984. A revised set of differentials, recommended by EC COST Action 817, will be introduced next season (Appendix 1).

Table 4 Differential cultivars used in seedling virulence tests in 1997

Differential Cultivar	**WYR Factor**	**Gene**
<u>Main set</u>		
Chinese 166	WYR 1	Yr1
Heines VII	WYR 2	Yr2
Cappelle Desprez	WYR 3	Yr3a + 4a
Hybrid 46	WYR 4	Yr3b + 4b
Heines Kolben	WYR 6	Yr6
Tommy	WYR 7	Yr7
Compair	WYR 8	Yr8
Kavkaz x 4 Federation	WYR 9	Yr9
<u>Additional set</u>		
Carstens V	WYR CV	
Hereward	WYR CV+	
Rendezvous	WYR 17	Yr17
Brigadier	WYR 9,17	Yr9+Yr17
Madrigal	WYR 6,9,17	Yr6+Yr9+Yr17
Cadenza	WYR Rx (Tonic)	
Parade	WYR R	

Table 5 Virulence factor frequency % (from natural infection)

Year		**'83**	**'84**	**'85'**	**'86**	**'87**	**'88**	**'89**	**'90**	**'91**	**'92**	**'93**	**'94**	**'95**	**'96**	**'97**
WYV 1		85	75	76	78	87	68	62	85	91	88	89	65	90	97	100
WYV 2		100	100	100	100	100	100	100	100	100	100	98	100	99	97	100
WYV 3		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 4		20	31	45	70	47	78	97	91	86	86	89	86	67	59	47
WYV 6		26	64	90	96	89	72	57	69	64	88	68	41	35	16	1
WYV 7		0	3	3	22	8	6	2	9	19	7	8	4	0	3	7
WYV 8		0	0	*	*	*	*	*	*	0	0	0	0	0	0	0
WYV 9		23	31	3	4	5	66	99	94	88	76	84	94	95	97	99
<u>Virulence for cultivars in additional set</u>																
Carstens V	WYR CV												75	55	9	13
Hereward	WYR CV+										36	47	35	10	6	10
Rendezvous	WYR 17													57	84	99
Brigadier	WYR 9,17											40	35	10	78	98
Cadenza	WYR Rx										0	2	0	0	0	0
Parade	WYR R										3	0	0	0	0	0
Madrigal	WYR 6,9,17														0	1
No. of isolates		63	36	29	23	52	71	156	67	42	77	63	49	83	32	138

Seedling virulence frequencies are given in Table 5. The frequencies of WYV 1, WYV 2, WYV 3, WYV 9 and WYV 17 were at, or close to, 100%. The high frequency of the latter two virulences reflects the domination of the national wheat acreage by susceptible WYR 9,17 cultivars.The frequency of WYV 4 continued to decline, reaching 47%. WYV 6 fell to an extremely low level, but is likely to increase as cultivars with the WYR 6,9,17 resistance, such as Equinox and Madrigal, become more widely grown. It is estimated that these cultivars will occupy around 6% of the winter wheat acreage in 1998.

The two most common pathotypes were WYV 1,2,3,9,17 (45%) and WYV 1,2,3,4,9,17 (36%).

ADULT PLANT TESTS

Four isolates from the 1996 survey (Table 6) and the control Yr17-virulent isolate 94/519, were tested for virulence on adult plants of 48 cultivars in Polythene tunnels and on seedlings of the same cultivars. The isolates were chosen on the basis of their seedling virulence phenotypes a 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
94/519	Hussar	Cambs[1]	1,2,3,9,17
96/17	Brigadier	Lincs	1,2,3,4,9,17
96/502	Madrigal	Cambs[2]	1,2,3,6,9,17
96/31	Hereward	Lincs	3,4,6,CV
96/34	Victo	Lincs	1,2,3,4,7,9,(17)

[1] inoculated polythene tunnel test
[2] inoculated field plot

Adult plant polythene tunnel test results are given in Table 7. Letters in brackets refer to the boxes marked in the table.

Both 94/519 (the original WYV 17 isolate) and 96/17 were virulent on WYR 17 cultivars (A). The severity of infection varied substantially according to the cultivars' background resistance. 96/17 appeared to be generally more aggressive than 94/519, giving higher levels of infection on most cultivars. The two isolates were virulent on WYR 9 (D) and on the adult plant resistance WYR 14 (L). 96/17 also showed increased virulence for WYR 13, but the result for 94/519 was less clear cut (K). There were indications of specific interactions between 96/17 and certain cultivars, most noticeably Hussar, Drake (A) and Slejpner (D), but further tests would be required to establish repeatability.

96/502 infected cultivars purported to carry the resistance combination WYR 6,9,17, which had previously been resistant to all isolates (C).This confirmed the results of seedling tests reported in 1997. Consistent with this, 96/502 was virulent on WYR 9,17 (A) and WYR 6,9 (G).

Isolate 96/31 was virulent on cultivars carrying the Carstens V resistance (H), as predicted from seedling test results. Some contamination of the test with WYV 9,17 is evident in the results (B and F).

Adult plant results confirmed that 96/34 possesses combined virulence for WYR 9 (E) and WYR 7 (M) together with virulence for the adult plant resistance WYR 14 (L). This is a relatively unusual combination in the UK. The suspected virulence of 96/34 for WYR 17 was not confirmed.

Virulence for WYR 11 (Joss Cambier) was last examined in UKCPVS polythene tunnel tests in 1978, when the cultivar became severely infected by virulent isolates. In that year, the levels of infection on Joss Cambier were similar to those observed in reactions between Clement (WYR 9) and virulent isolates. Comparison of Clement (D,E) with Joss Cambier (J) in the 1997 tests indicates that none of the isolates tested possessed virulence for WYR 11. Similarly, there was no evidence of virulence for the adult plant resistance WYR 12, last checked in 1986.

Five cultivars marked with an asterisk were tested for the first time in polythene tunnel tests. One of these, Savannah, was added to the NIAB Recommended List for 1998. The yellow rust resistance of all five is based on WYR 17, leading to increased concern about the lack of diversity of resistance in the cultivars coming through to commercialisation.

The resistances of the cultivars in the lower part of the table remained effective and appear to offer useful alternative sources of resistance, at least for the immediate future.

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Table 7 Adult plant tests 1997. Mean% leaf area infection (mean of 4 assessments)

Cultivar	Isolate WYR[1]	94/519	96/17	96/502	96/31	96/34
		Virulence in seedling tests given inTable 6				
Brigadier	9,17	29	41	27	29	Tr
Hussar	9,17	1	17	2	0	2
Reaper	9,17	18	19	16	4	3
Rendezvous	9,17	8	10	7	0	0
Drake	9,17	1	11	3	0	0
Harrier	9,17	6	18	9	6	6
Beaufort	9,17	5	15	6	3	1
Abbot	17	4	2	1	0	0
Blaze*	9,17	19	36	17	10	7
Cantata*	9,17	2	2	Tr	0	Tr
Chaucer*	17	2	3	1	0	0
Maverick*	9,17	15	6	10	Tr	5
Savannah*	9,17	10	18	13	7	6
Equinox	6,9,17	Tr	Tr	2	0	0
Madrigal	6,9,17	Tr	2	17	0	0
Lynx	6,9,17	0	0	3	0	0
Slejpner	9	8	28	11	8	3
Clement	9	20	15	15	9	14
Haven	6,9	Tr	0	14	0	0
Rialto	6,9	0	0	3	0	0
Hornet	6,9	0	2	19	0	Tr
Hereward	CV+	0	0	0	4	Tr
Spark	CV+	0	1	Tr	1	0
Consort	CV+	0	0	0	0	0
Talon	CV+	Tr	0	0	13	1
Carstens V	CV	0	0	0	Tr	0
J.Cambier	11	5	8	4	Tr	3
Armada	12	0	0	0	0	0
Mega	12	0	0	1	0	0
Riband	13	2	9	5	0	8
M.Huntsman	2,13	2	6	0	0	2
Hustler	1,2,13	4	16	1	1	1
Crofter	?13	3	8	5	0	1
Hobbit	14	12	20	7	8	15
Brock	7,14	0	0	0	0	15
Soissons	?3	0	2	0	0	Tr
Caxton	6	0	Tr	Tr	0	0
Charger	?6+APR	0	0	0	Tr	0
Hunter	6,9+APR	0	0	0	0	0
Encore	6,9+APR	0	0	0	0	0
Apostle	2,6+APR	0	0	0	0	0
Mercia	3+APR	0	0	0	0	0
Tonic	R Tonic	0	0	0	0	0
Cadenza	R Tonic	0	0	0	0	0
Axona	Rx	0	0	0	0	0
Dynamo	Rx + APR	0	0	0	0	0
Parade	R	0	0	0	0	0
Buster	R	0	0	0	0	0

[1] Presence or absence of WYR3 has not been confirmed as all isolates used in recent tests possess WYV3 Where WYR 3 is indicated, this is based on evidence from elsewhere.

Boxes are used to highlight discussion points and have no statistical significance.

APPENDIX 1.

COST ACTION 817

Core Set of Differential Cultivars for Yellow Rust of Wheat (*Puccinia striiformis*)

Differential cultivar	Yr gene
Chinese 166	Yr 1
Kalyansona	Yr 2
Vilmorin 23	Yr 3a+
Nord Desprez	Yr 3a+
Hybrid 46	Yr 3b, Yr 4b
Heines Peko	Yr 6, Yr 2
Heines Kolben	Yr6, (? Yr 2)
Lee	Yr 7
Reichersburg 42	Yr 7 +
Compair	Yr 8
Kavkaz x 4 Federation	Yr 9
Moro	Yr 10
Yr15/6*AvS	Yr 15
VPM 1	Yr 17
Carstens V	CV
Avocet 'R'	Yr A +
Suwon 92 x Omar	So
Strubes Dickkopf	Sd
Spaldings Prolific	Sp

BROWN RUST OF WHEAT

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Seedling tests identified virulence to cvs Sterna (WBR-7) and Sabre (WBR-7) carried by two isolates cultured from an infected crop of cv. Chablis. Adult plant tests in controlled environments confirmed one of these isolates as carrying virulence to cv. Chablis as well as to cvs Savannah and Chaucer. Winter and spring wheat cultivars sown in field isolation nurseries expressed generally high levels of resistance to the three isolates to which they were exposed.

GLASSHOUSE SEEDLING TESTS WITH 1997 ISOLATES

The geographic and cultivar origins of the 4 samples of wheat brown rust received in 1997 are given in Table 1.

Table 1 Origins of wheat brown rust samples received in 1997.

Isolate	Location	Cultivar
WBRS-97-1	?	Riband
WBRS-97-2	Essex	Riband
WBRS-97-3	Lincolnshire	Chablis
WBRS-97-4	Lincolnshire	Chablis

Isolates of *Puccinia recondita* cultured from the samples were tested on a set of differential cultivars which comprised the standard WBR cultivars, cv. Thatcher backcross lines carrying different Lr resistance factors and other spring and winter wheat cultivars (Table 2).

The Thatcher backcross lines include those comprising the standard common set agreed amongst European leaf rust workers.

Seedlings were grown and inoculated under standard conditions and, following incubation in dew simulation chambers, were transferred to either of two post-inoculation environments, a low temperature regime (10°C and 12 h photoperiod) and a high temperature regime (25°C and 16 h photoperiod).

Table 2 Differential cultivars

Standard differential cultivars (WBR-factor)	Thatcher Lr lines		Spring and winter cultivars
Clement (1)	Lr 1	Lr 15	Paragon
Fundin (2)	Lr 2a	Lr 17	Samoa
Norman (2)	Lr 2b	Lr 19	Canon
Hobbit (2)	Lr 2c	Lr 20	Rialto
Sappo (3)	Lr 3	Lr 21	Harrier
Maris Halberd (4)	Lr 3bg	Lr 23	Nemesis
Gamin (6)	Lr 3ka	Lr 24	Shamrock
Sterna (7)	Lr 9	Lr 26	Shango
Sabre (7)	Lr 11	Lr 28	Claire
Armada (0)	Lr 13	Lr 37	Malacca
	Lr 14a		Aardvark

Results

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

Isolate	Virulence combination
WBRS-97-1	0
WBRS-97-2	1,2
WBRS-97-3	1,2,7
WBRS-97-4	1,2,7

Three of the isolates carried virulence factors 1 and 2 which have been identified at a high frequency in the survey samples in recent years. These virulences were combined with WBV-7 in two of the 1997 isolates.

Of the additional spring and winter wheat cultivars, Canon, Rialto and Harrier were resistant at 10°C and 25°C to 3 of the isolates but were susceptible at 25°C (mixed reaction) to isolate WBRS-97-4 with cv. Rialto also being susceptible at 10°C to the same isolate. Cultivars Claire and Malacca responded similarly, being susceptible to all isolates except WBRS-97-3 at 25°C. Conversely, cv. Nemesis was resistant to the isolates at both temperature regimes with the exception of the same isolate when it was susceptible at 10°C. Cultivar Shango was resistant, resistance being more effective at the higher temperature. The resistance of cv. Aardvark was effective at 10°C and 25°C to the four isolates but cvs Paragon, Samoa and Shamrock were susceptible.

The reactions of the Thatcher-Lr backcross lines, which carry known specific Lr genes, to the 1997 isolates are given in Table 3.

The temperature-sensitive resistances conferred by the 3 lines were effective at 25°C to two of the isolates but were overcome by isolates WBRS-97-3 and WBRS-97-4. These latter two isolates also carried virulence to the high temperature resistances of cvs Sterna (WBR-7) and Sabre (WBR-7). Isolates carrying virulence to the Lr3 lines have previously been the only ones virulent on cvs Sterna and Sabre, suggesting they carry a common resistance. The reactions of cv. Chablis, from which both isolates WBRS-97-3 and WBRS-97-4 were cultured, have previously suggested that it also carries resistance factor WBR-7. The line Lr17 showed a similar pattern of responses to the isolates.

The line Lr26, like cv. Clement (WBR-1), was susceptible to 3 of the isolates but was resistant at both 10°C and 25°C to isolate WBRS-97-1. The temperature-sensitive resistance of Lr23, effective at the higher temperature, was overcome by isolate WBRS-97-2 as was the resistance of Lr15 by isolate WBRS-97-3.

Resistances conferred by Lr19, Lr24 and Lr28 were effective at both temperature regimes. Lines Lr13 and Lr37, included in tests for the first time, were susceptible to the 1997 isolates.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Forty-one winter and thirteen spring wheat cultivars were sown in each of three nurseries in the 1996-1997 season using standard procedures (Clifford, Jones and Priestley, 1978). The nurseries were each inoculated with one of the following isolates of *P. recondita.*

Isolate	Origin
WBRS-96-1	cv. Caxton, Sussex
WBRS-94-50	cv. Flame, Norfolk
WBR-1947-77	Unknown, Czech Republic

Results

These are summarised in Table 4. Good levels of disease built up on the spreader cultivar within the winter nurseries with the susceptible check cultivars becoming heavily infected. Disease was slower to establish within the spring nurseries although reasonable levels of infection were established on a susceptible cultivar by the end of the season. The majority of the cultivars were highly resistant to the isolates. The failure to identify virulences in the pathogen population compatible with the resistances carried by many of the current NIAB recommended wheat varieties makes it difficult to identify different specific resistances that these cultivars may carry. Cultivars are grouped within Table 4 on the basis of their responses to the isolates in 1997 tests as well as on data of previous years' seedling and adult plant tests. It should not be interpreted that cultivars within a group carry a common resistance factor(s).

Group 1: Only isolate WBRS-94-50 infected cv. Clement (WBR-1). This isolate was identified in 1994 seedling and 1995 adult plant field tests as carrying the corresponding virulence factor but failed to infect cv. Clement in 1996 field tests. Neither isolate WBRS-96-1 nor WBR-1947-77 were identified as carrying virulence factor WBV-1 in seedling tests.

Group 2: Cultivar Fundin (WBR-2) was susceptible to the isolates. The temperature-sensitive resistance of this cultivar had been effective at 25°C to isolates WBRS-96-1 and WBR-1947-77 in previous seedling tests. Cultivars Hobbit and Norman, which carry additional resistance to Fundin (Clifford *et al.*, 1982), were less heavily infected by each of the isolates.

Group 3: Cultivar Sappo (WBR-3) was the only spring wheat to show high levels of susceptibility within the nurseries. Isolate WBRS-96-1 carried virulence to it in seedling tests, the other two isolates infecting it at 25°C only.

Group 5: The adult plant resistance(s) of cvs Huntsman and Mercia were ineffective against the isolates. Pathotypes differentiating the resistances of these cultivars have been identified in previous years.

Group 6: Isolate WBRS-94-50 had overcome the resistance(s) of cvs Gamin (WBR-6) and Dynamo in 1995 field nurseries but failed to do so in 1996 and 1997 field tests when their adult plant resistance was effective.

Group 9: Cultivars within this group were also susceptible to isolate WBRS-94-50 in 1995 isolation nurseries but have expressed resistance in subsequent years' field tests.

Groups 10-12: The resistances of these cultivars were effective.

Group 13: Cultivars showed generally low levels of infection to the isolates, including cv. Imp which had previously (1995) been susceptible to isolate WBRS-94-50.

CONTROLLED ENVIRONMENT TESTS

Thirty-two winter and spring wheat cultivars were grown in spore-proofed conditions to the flowering stage of growth. Two replicates of each cultivar were inoculated with one or other of the isolates:

Isolate	Origin
WBRS-94-50 ex Crofter	cv. Flame, Norfolk
WBRS-97-3	cv. Chablis, Lincolnshire

The first isolate was cultured from infected leaves (0.4% infection) of cv. Crofter grown in an isolation nursery at IGER into which was introduced isolate WBRS-94-50. It failed to infect any of the standard differential cultivars at both 10°C and 25°C in seedling tests with the exception of cv. Gamin (WBR-6, adult plant resistance). Cultivar Clement (WBR-1) expressed a mixed, mainly resistant reaction to the isolate.

Isolate WBRS-97-3 was cultured from infected leaves of cv. Chablis sampled from a site in Lincolnshire which had shown infection levels of around 15%. Seedling tests showed it to carry virulence factors 1, 2 and 7. Following incubation in dew simulation chambers, the plants were transferred to either of two post-inoculation environments, a low temperature regime (10°C and 12 h photoperiod) and a high temperature regime (25°C and 16 h photoperiod).

Results

These are given in Table 5. Assessments of percentage flag leaf area infection and of reaction type were made 10 days post-inoculation at 25°C and 26 days post-inoculation at 10°C. The cultivars have been grouped within the table on the basis of their patterns of response to the two isolates.

Group 1: Cultivars resistant, although high levels of infection of a resistant or mixed resistant type were observed, especially on cultivars inoculated with isolate WBRS-97-3 and incubated at 25°C.

Group 2: Cultivars susceptible only to isolate WBRS-97-3 at the higher temperature regime. They were resistant to it at 10°C and were also generally more resistant at the lower temperature to isolate WBRS-94-50 ex Crofter.

Group 3: Cultivars showed high levels of disease to isolate WBRS-97-3. These included cvs Chablis, Savannah and Chaucer, all of which have NIAB disease ratings of 9 for brown rust resistance and which have shown generally high levels of resistance in adult plant tests at IGER. Those tests included ones carried out under controlled environments and in the field with isolate WBRS-95-19 which, like isolate WBRS-97-3, was sampled from an infected crop of cv. Chablis showing unexpectedly high levels of disease. This isolate failed to infect cv. Chablis in the 1996 field nurseries and induced lower levels of disease on it in controlled environment tests in 1995 (1% at 10°C, 7% at 25°C) than would be expected from the severity of the attack on the original sample. The high levels of infection shown by cv. Chablis at both temperature regimes in the current year's controlled environment tests suggest that virulence to this cultivar may be confirmed in 1998 field tests. Also infected was cv. Sterna (WBR-7). Previous seedling test data (Jones and Clifford, 1996) have suggested that cvs Chablis and Sterna carry a common resistance with the Lr3 group of Thatcher-backcross lines also reacting similarly to the different isolates.

Group 4: The low temperature resistance of cv. Sappo (WBR-3) was effective.

Group 5: The adult plant resistance of cv. Fury was overcome by isolate WBRS-97-3 but was effective at 10°C to isolate WBRS-94-50 ex Crofter. It had also been resistant in the 1997 field nursery inoculated with WBRS-94-50.

Group 6: Cultivar Rialto was susceptible to WBRS-94-50 ex Crofter but was infected at only very low levels by isolate WBRS-94-50 in the field isolation nurseries. It was resistant to WBRS-97-3.

Group 7: Cultivar Fundin (WBR-2) was susceptible to isolate WBRS-97-3 which was identified as carrying the corresponding virulence in seedling tests.

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Table 3 Reaction† of Thatcher-Lr backcross lines to 1997 isolates of *P. recondita* at two temperatures, 10°C and 25°C.

Isolate	Post inoculation incubation temperature	Thatcher Line (Lr gene)										
		Lr1	Lr2a	Lr2b	Lr2c	Lr3	Lr3bg	Lr3ka	Lr9	Lr11	Lr13	Lr14a
WBRS-97-1	10°C	S	-	-	-	MS	MS	MS	R	MR	S	S
	25°C	R	R	R	MS	R	R	R	R	MS	S	S
WBRS-97-2	10°C	S	S	MS	S	MS	S	MS	MS	S	S	S
	25°C	R	R	MS	MS	R	R	R	R	MS	S	S
WBRS-97-3	10°C	S	S	S	S	S	S	S	MR	S	S	S
	25°C	R	R	MS	S	S	S	S	R	S	S	S
WBRS-97-4	10°C	S	-	S	S	S	S	S	MR	S	S	S
	25°C	MR	-	MS	MS	S	S	S	R	MS	S	S
		Lr15	Lr17	Lr19	Lr20	Lr21	Lr23	Lr24	Lr26	Lr28	Lr37	
WBRS-97-1	10°C	R	S	R	MR	MR	S	MR	R	R	S	
	25°C	R	R	R	MR	R	R	R	R	R	S	
WBRS-97-2	10°C	R	S	R	MR	MR	S	R	S	R	S	
	25°C	R	R	R	MS	MR	S	R	S	R	S	
WBRS-97-3	10°C	S	S	R	MR	MR	S	MR	S	R	S	
	25°C	MS	MS	R	MR	MR	R	R	S	R	S	
WBRS-97-4	10°C	MR	S	R	MR	MR	S	MR	S	R	S	
	25°C	MR	MS	R	MR	MR	R	R	S	R	S	

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

Table 4 Percentage infection† of spring and winter wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1997

Cultivar [NIAB rating]	Group	WBR factor	Isolate WBRS-96-1	 WBRS-94-50	 WBR-1947-77
Clement	1	1	0	6	0
Rialto [4]			0	1	0
Fundin	2	2	12	19	16
Norman		2+	1 MS	2 MS	3 MS
Hobbit		2+	1 MS	2 MS	2 MS
Sappo	3	3	22	26	19
Halberd	4	4	0	0.3	0.5 MR
Huntsman	5	5 APR	23	30	33
Mercia [4]		APR	20	30	30
Gamin	6	6 APR	0	0	0
Dynamo [7]		APR	0	0	0
Sterna	7	7	Trace R	0	0
Sabre		7	0	0	0
Chablis [9]		7	0	0	0
Shiraz [9]		7+ ?	0	0	0
Ranger	8	8 APR	0	0	0
Avans [(3)]		OR ?	0	0	0
Kinsman			0	0	1 R

Table 4 (continued)

			Isolate		
Cultivar [NIAB rating]	Group	WBR factor	WBRS-96-1	WBRS-94-50	WBR-1947-77
Avalon	9	9 APR	0.2	1	0.5
Buster [3]		APR	0	0.1	0.1
Riband [4]			0.5	1	1
Spark [8]	10	APR	0	0	0
Hereward [7]		APR	0	0	0
Consort [6]		APR	0	0	0
Brigadier [9]	11	OR	0	0	0
Hussar [8]		OR	0	0	0
Beaufort [9]		OR ?	0	0	0
Cadenza [8]	12		0	0	0
Reaper [9]			0	0	0
Encore [9]			0	0	0
Caxton [8]		APR	0	0	0
Cantata [(6)]		APR	0	0	0
Maverick [9]		APR	0	0	0
Blaze [9]		OR	0	0	0
Savannah [9]		OR	0	0	0
Madrigal [9]		OR	0	0	0

Table 4 (continued)

			Isolate		
Cultivar [NIAB rating]	Group	WBR factor	WBRS-96-1	WBRS-94-50	WBR-1947-77
Harrier [9]		OR	0	0	0
Abbot [9]			0	0	0
Drake [9]		OR	0	0	0
Equinox [9]		OR	0	0	0
Charger [(5)]			0	0	0
Baldus [7]		APR+OR	0	0	0
Ebony [(R)]		APR+OR	0	0	0
Soissons [3]	13	APR	0.2	0.3 MS	0.4
Crofter [4]		OR	0	0.4	0
Chaucer [9]		APR	0	Trace R	0.3 R
Axona [9]		APR	0	0	0.1
Samoa			0	0	Trace R
Imp [4]		APR	0	0	1
Paragon		APR	0	0	0.1
Fury [(VS)]		APR	Trace	0	5
Armada	14	0	20	33	26
Arina			45	58	49

† 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.[ ] NIAB rating: 1 = susceptible; 9 = resistant; ( ) = limited data; R = resistant; VS = very susceptible

Table 5 Reactions† of winter and spring wheats (adult plants) to specific isolates of *P. recondita* at 10°C and 25°C.

Isolate		**WBRS-94-50 ex Crofter**		**WBRS-97-3**	
Incubation Temperature °C		**10**	**25**	**10**	**25**
Cultivar [NIAB rating]	**Group**				
Abbot [9]	1	0	0	0	0
Harrier [9]		0	0	0	10 MR
Reaper [9]		0	0	0	15 MR
Equinox [9]		0	0	0	25 R
Hussar [8]		10 R	0	0	5 R
Consort [6]		0	18 R	0	18 R
Blaze [9]		20 MR	0	15 R	12 MR
Maverick [9]		23 MR	20 MR	0	8 R
Avans [(3)]		0	38 MR	5 R	33 MR
Baldus [7]	2	12 MR	4 R	15 MR	25
Halberd		12 R	23 R	5 R	12
Paragon		5 R	20 MR	5 R	18
Shiraz [9]		0	0	5 R	15
Caxton [8]		0	0	20 MR	23
Cadenza [8]		0	18 R	0	18
Cantata [(6)]		0	3 R	0	28 MS
Axona [9]		0	23 MR	0	10 MS
Samoa		0	25 R	0	20
Spark [8]	3	0	0	13	13
Sterna		0	0	9	23
Chablis [9]		0	0	20	23
Savannah [9]		0	0	15	18
Buster [3]		0	0	20	30
Gamin		0	10 R	8	20
Imp [4]		0	15 R	13	23
Soissons [3]		0	20 MR	23	28
Chaucer [9]		9 MR	0	18	23
Sappo	4	0.2	33	0.1	18
Fury [(VS)]	5	10 R	33 MS	18	28
Rialto [4]	6	28	13	0	10 MR
Fundin	7	13	28	10	23
Riband [4]		20	35	15	18

†Percentage flag leaf area infected (mean of 2 replicates); All reactions susceptible unless stated. R = resistant; MR = mixed resistant; MS = susceptible. [ ] NIAB rating: 1 - susceptible; 9 = resistant; ( ) = limited data; VS = very susceptible.

BROWN RUST OF WHEAT: NIAB ADULT PLANT TESTS

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METHODS

Three spreader beds of winter wheat cultivars were inoculated with different isolates of brown rust (*Puccinia recondita*), as part of the Recommended List testing programme funded by the Home-Grown Cereals Authority. Methods used were similar to those employed in recent years, although an isolate mixture was used for the third bed in 1997. Details of the isolates used are shown in Table 1 and the test results, expressed as the mean infection in two replicates assessed on two occasions, given in Table 2.

Table 1 Isolates of wheat brown rust used in adult plant tests, NIAB Cambridge, 1997

Isolate (Probable virulence)	Origin of isolate
WBRS-91-65 (1,2,3,4 Soissons, Pastiche)	Pastiche, Cambs, 1991
WBRS-95-19 (1,2,5,7)	Chablis, Suffolk, 1995
WBRS-91-67 (1,2,Virtue,Buster)	Virtue, Cambs, 1991
WBRS-93-84 (2,5,9,Virtue, Buster)	Buster, Avon, 1993
WBRS-94-50 (1,2,6?)	Flame, Norfolk, 1994

RESULTS

In Table 2, cultivars have been grouped according to their response to infection by the individual, or mixture of, isolates. This does **not** imply that cultivars in the same group possess common resistance factors.

Infection again proved difficult to establish, as in 1996 (Clarkson & Mann, 1997). The susceptible cultivars Mercia and Riband were infected by all isolates, whereas Krakatoa, Pastiche and Soissons were susceptible to 95-19 and 91-65 only. Crofter, Equinox and Madrigal were only infected by 91-65. Maris Huntsman reacted to 91-65 and the isolate mixture but not to 95-19, unlike in IGER 1996 tests (Jones & Clifford, 1997). Avalon, Buster and Caxton reacted to the isolate mixture only.

Thirty-six cultivars exhibited no infection by the individual isolates or the mixture. This does not necessarily imply that these cultivars are resistant to brown rust, particularly as the susceptible cultivars Haven and Rialto also remained uninfected.

Table 2 Reactions of winter wheat cultivars to infection by brown rust isolates in spreader bed tests, NIAB Cambridge, 1997 (Newer varieties in *italics*)

Cultivar (NIAB rating)*		% infection with brown rust		
		95-19	**91-65**	**Mixture^**
Mercia	(3)	8.8	11.8	15.5
Riband	**(4)**	2.0	17.8	4.0
M Huntsman	(5)	0	19.3	19.3
Krakatoa	*(5)*	1.8	6.3	0
Pastiche	(8)	3.0	15.5	0
Soissons	**(2)**	2.0	23.5	0
Crofter	*(4)*	0	13.0	0
Equinox	***(9)***	0	0.3	0
Madrigal	***(9)***	0	0.3	0
Avalon	(5)	0	0	4.3
Buster	**(3)**	0	0	10.0
Caxton	**(8)**	0	0	0.3

The following cultivars showed **NO** infection:-

***Abbot* (9)**, *Banker (9)*, **Beaufort (9)**, *Blaze (9)*, **Brigadier (9)**, **Cadenza (8)**, *Cantata (8)*, ***Charger* (8)**, *Chaucer (9)*, Chianti (6), **Consort (6)**, *Drake (9)*, Dynamo (8), Encore (9), *Falstaff (9)*, Flame (8), ***Harrier* (9)**, Haven (3), **Hereward (7)**, Hunter (9), **Hussar (9)**, Magellan (9), *Malacca (8)*, *Maverick (9)*, *Oberon (9)*, *Pride (9)*, Raleigh (9), **Reaper (9)**, **Rialto (4)**, ***Savannah* (9)**, *Shango (9)*, Slejpner (8), **Spark (8)**, *Tiller (9)*, Virtue (9), *Weston (9)*.

* 1-9 scale: higher values indicate increasing resistance. (Last recorded rating given; 1998 NIAB Recommended List varieties in **bold**.)

^ Mixture of isolates 91-67, 93-84 and 94-50.

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MILDEW OF BARLEY

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Virulence factors corresponding to resistance factors in current barley cultivars were recorded at similarly high levels to previous years. The population remains complex with isolates carrying up to 13 virulence factors. There was no dominant pathotype, the commonest occurring in only 8% of the samples. The only effective specific resistance continues to be *mlo*, although many winter cultivars possess good levels of non-specific resistance.

INTRODUCTION

The dry, mild spring of 1997 encouraged early spread of mildew giving high levels of infection in some plots by the end of April. This facilitated the collection of excellent samples of powdery mildew from winter cultivars. Further development was arrested by wet conditions in May and June, resulting in a lack of good samples from spring cultivars.

METHODS

Single colony isolates taken from 95 of the 154 samples collected from infected leaves were tested to determine virulence factors. 48 of the samples failed to produce viable conidia, while a further 11 samples were not tested. Random samples of airborne spores were collected by exposing seedlings of cv. Golden Promise on high roofs at NIAB, Cambridge and Cambridge University.

Isolates from infected leaves were collected from the following 8 locations:

NIAB, Cambridge	68	isolates	Morley, Norfolk	14	isolates
Inverness, Scotland	35		Headley Hall, Yorks.	11	
South Runcton, Norfolk	19		Wye, Kent	8	
Bridgets, Hants.	15		Cockle Park, Northumb.	2	
			Total	172	

Isolates were collected from the following 11 spring and 26 winter cultivars:

<u>Spring cultivars</u>

Extract	7	isolates	Optic	6	isolates	Hart	2	isolates
Cooper	6		Prisma	6		Chariot	1	
Delibes	6		Riviera	6		Tankard	1	
Felicie	6		Chalice	3				

Winter cultivars

Jewel	9	isolates	Sunrise	6	isolates	Manitou	4	isolates
Baton	8		Linnet	5		Gleam	3	
Regina	7		Muscat	5		Pipkin	3	
Vertige	7		Peridot	5		Epic	2	
Fanfare	6		Rifle	5		Puffin	2	
Gaelic	6		Angora	4		Spice	2	
Intro	6		Fighter	4		Sprite	2	
Melanie	6		Halcyon	4		Pastoral	1	
Spirit	6		Hanna	4				

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

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

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

RESULTS

Virulence

The frequencies of virulence factors in isolates of barley mildew in 1997 are shown in Table 2. *Vh, Vg* and *V(CP)* were all present at high levels in the populations, particularly in the leaf samples. The random populations collected from the roof in June and October were probably influenced more by spring cultivars, which lack the corresponding resistance factors, and hence showed lower levels of these virulences. All of the isolates tested carried *Vra*. Although at lower levels generally, *Va6* was also reduced in the June and October roof samples. There is selection for this virulence factor during the winter as the resistance factor *Mla6* is carried by the winter cultivars Epic, Sunrise and Gleam which together make up 51% of the barley area.

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 relative area of barley cultivars with the corresponding resistance factors in 1997.

		Frequency of virulence factors (%)					
		Leaf sample		Random samples of airborne spores			
Virulence gene	Virulence factor	All data	Non-corresponding virulence *	March	June	October	Area of corresponding resistance (%)
Vh	1a	77	72	70	59	56	18
Vra	1b	100	100	100	100	100	31
Vg	2a	98	97	95	98	89	42
V(CP)	2b	97	96	92	95	81	42
Va6	3	37	32	22	17	15	51
VLa	4	58	57	52	68	59	2
Va12	5	88	85	60	77	68	5
Vk1	6a	68	68	75	66	72	0
Va7	6b	70	70	77	65	80	0
V(Ab)	6c	67	63	45	49	42	14
Va1	7	52	49	27	34	26	2
Va9	8	34	30	33	30	31	<1
vo	0	0	0	0	0	0	17
Va13	10	26	24	51	33	47	2
Va3	11	2	2	1	0	1	0
Number of isolates		172		201	100	78	

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

There was little difference in the levels of *VLa*, although the highest levels were recorded in the June and October roof samples. The spring cultivar Cooper carries *MlLa* but represented only 2% of the barley grown in 1997. There is no selection for *Vk1* and *Va7* but these virulences remain at moderately high levels in all the populations sampled. *Va9* was detected in about 30% of the samples, although the corresponding resistance occurred in less than 1% of the barley area grown. The level of *Va13* in the leaf samples was lower than that in the roof populations. Although there was selection from only 2% of the area of barley grown, there were moderately high levels remaining in the general population. The leaf samples were not collected randomly and few were from *Mla13* cultivars which probably explains the lower level of virulence in these samples.

The lower levels of *Va12* in the March and October samples are difficult to explain. There was some selection for this virulence factor all the year round, from the spring cultivars Prisma and Optic and the winter cultivars Puffin, Rifle and Jewel. However, these cultivars together made up only 5% of the barley grown in 1997.

Table 3 Virulence frequencies in barley mildew, 1991 to 1997.

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

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

\- No data

Virulence for the majority of the resistance factors tested has changed little over the last few years, as shown in Table 3. *Vh, Vra, Vg, V(CP), Va12, Vk1, Va7, Va9, Va13* and *Va3* have all remained stable since 1991. Although selection for *Vh, Va12, Vk1* and *Va7* is small, these virulence factors remain at a high level in the mildew population. There has been continuous selection for *Vra* over the last twenty-five years resulting in its maximum occurrence. *Vg* and *V(CP)* remain high due to continuing selection. The levels of *Va9* and *Va13* remain stable at around 30% and 40% respectively, although selection for these factors has decreased over the last few years. No barley cultivars containing *Mla3* have been grown in the UK but virulence for this resistance factor remains present in the population, albeit at a very low level.

Following an increase in 1991 to 1993, due perhaps to the introduction of the winter cultivar Torrent in the late eighties, selection by Epic, Sunrise and Gleam has resulted in the levels of *Va6* remaining at around 30%. The frequency of *V(Ab)* showed a decrease in 1997 after remaining stable for several years. Only 14% of the barley area now selects for this virulence factor compared to about 25% in the early and late eighties. However, in the past, like *Vk1* and *Va7*, this virulence has continued to occur frequently in the population when selection has declined. The largest change over the last few years has seen *VLa* increase from 22% in 1993 to 58% in 1997. This probably reflects the increase in popularity of Cooper (*MlLa, Mla1*) in 1994 and 1995.

Complexity of isolates

Table 4 Number of virulences carried by isolates of barley mildew in 1997

No. of virulence factors	Frequency of isolates with each number of virulences*			
	Leaf samples	Random samples of airborne spores		
		March	June	October
0	0	0	0	0
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	2	2	1
5	0	5	7	4
6	6	11	13	19
7	15	19	16	22
8	22	20	27	26
9	27	23	14	14
10	21	12	17	13
11	6	5	2	1
12	2	1	2	0
13	1	0	0	0
No. of isolates	172	201	100	78

* includes all virulences listed in Table 2 except *Va3*

As in previous years the leaf samples yielded more complex isolates. Table 4 shows that, while the majority of the leaf samples had 8-10 virulences, the majority of the roof samples had 6-9. These values are similar to 1996 although there has been a gradual increase in the complexity of the population since 1990 (Table 5). Isolates with fewer than six virulence factors are now uncommon.

Table 5 Comparison of the complexity of isolates collected in 1991 to 1997.

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

* includes all virulences listed in Table 2 except *Va3*

Frequencies of the most common pathotypes

Again there was no predominant pathotype in the barley mildew population, contrasting greatly with the wheat mildew population (Clarkson & Slater, 1997). Pathotype *VLa,Va12,Vk,Va7,V(Ab),Va1* occurred most frequently, being present in 8% of the June roof samples but in only 4% of the total samples. Table 6 shows the number of pathotypes identified in the last three years. The number of pathotypes, relative to the number of isolates tested, remains similar with just over half the pathotypes represented by a single isolate.

Table 6 The number of pathotypes identified in 1995-1997.

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

Due to the complex nature of the barley mildew population and the high frequencies of many of the virulence factors corresponding to the resistance of current commercial cultivars, most winter barley cultivars are potentially very susceptible. Table 7 shows the proportion of the population that was able to infect the cultivars currently in NIAB Recommended List Trials. Hanna, Halcyon (no resistance), Intro, Linnet, Muscat and Pastoral (*Mlra*) are susceptible to the whole of the population and hence high levels of infection can be expected on these cultivars. However, Halcyon and Intro also possess moderate levels of non-specific resistance (NIAB rating 6). Fanfare, Puffin, Rifle, Jewel, Angora and Melanie can be infected by more than 60% of the population and rely on non-specific resistance for protection from mildew. Pipkin and Manitou are both very susceptible and Pipkin, particularly, has very poor non-specific resistance. Epic is the most resistant of the winter cultivars, infected by only 25% of the population, and has good non-specific resistance (NIAB rating 8). Gleam, the most popular winter barley representing 11% of the winter barley area in 1997, is also susceptible to only 25% of the population.

Table 7 The proportion of mildew isolates tested in 1997 able to infect the barley cultivars in Recommended List trials (NIAB rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Hanna (4)	100	Rifle (7)	73
Halcyon (6)	100	Jewel ((7)	73
Intro (6)	100	Angora (6)	68
Linnet (4)	100	Melanie (5)	68
Muscat 5)	100	Pipkin (2)	39
Pastoral (3)	100	Manitou (5)	33
Fanfare (5)	94	Gleam (6)	25
Puffin (6)	80	Epic (8)	25
Spring cultivars	**Proportion (%)**	**Spring cultivars**	**Proportion (%)**
Optic (7)	48	Chalice (9)	0
Prisma (3)	46	Dandy (9)	0
Delibes (6)	30	Derkado (9)	0
Cooper (7)	29	Hart (9)	0
Felicie (7)	27	Landlord (9)	0
Alexis (9)	0	Riviera (9)	0
Chariot (9)	0	Tankard (9)	0

Current spring cultivars have variable levels of resistance to mildew. Due to their declining popularity, virulence for Optic, Prisma, Delibes and Felicie is now less than 50%. Optic, Delibes and Felicie have moderate levels of non-specific resistance and infection levels in the field are thus potentially low. Prisma, however, has little non-specific resistance (NIAB rating 3) and is potentially very susceptible. The *mlo* cultivars Alexis, Chariot, Chalice, Dandy, Derkado, Hart, Landlord, Riviera and Tankard comprise 49% of the spring barley area. These cultivars remain completely resistant to powdery mildew.

Regina (3), Vertige (5), Fighter (8) and Gaelic (5) are not included in Table 7 since their resistance factors, and hence the corresponding virulences, remain unknown. However, their potential for infection in the field is shown by their NIAB ratings: only Fighter possesses good non-specific resistance.

Resistance factors in new cultivars

Table 8 Specific resistance genes of barley cultivars.

None	*Mlg,Ml(CP),Mla12*	*Ml(Ab),Mla1*
Halcyon (W)	Peridot (W)	Delibes (S)
Hanna (W)		
	Mlh,Mlg,Ml(CP),Mla12	*mlo*
Mlra	Spice (W)	Alexis (S)
Intro (W)		Chariot (S)
Linnet (W)	*Mlh,Mlra,Mlg,Ml(CP),Mla12*	Dandy (S)
Muscat (W)	Puffin (W)	Derkado (S)
Pastoral (W)		Hart (S)
Sprite (W)	*Mla12+?*	Landlord (S)
	Jewel (W)	Riviera (S)
Mlh,Mlra		Tankard (S)
Angora (W)	*Mla9*	
Melanie (W)	Manitou (W)	*mlo?*
		Chalice (S)
Mlra,Mlg,Ml(CP)	*Mlg,Ml(CP),Mla9*	Ferment (S)
Fanfare (W)	Felicie (S)	Livet (S)
Spirit (W)		
	Mla13	Uncertain
Mlra,Mlg,Ml(CP),Mla6	Pipkin (W)	Extract (S)
Epic (W)		Fighter (W)
	Mla12,Ml(Ab)	Gaelic (W)
Mlh,Mlra,Mlg,Ml(CP),Mla6	Optic (S)	Regina (W)
Gleam (W)		Vertige (W)
Sunrise (W)	*Mlg,Ml(CP),Mla12,Ml(Ab)*	
	Prisma (S)	
Mlra,Mla12		
Rifle (W)	*Ml(La),Mla1*	
Baton (W)	Cooper (S)	

(W) winter cultivar, (S) spring cultivar

The resistance factors for barley cultivars in NIAB trials in 1997 are shown in Table 8. No new resistance combinations were identified in the new cultivars. Three of the new winter cultivars, Baton, Jewel and Peridot, carry *Mla12*. Baton and Peridot also carry the ineffective resistances *Mlra* and *Mlg,Ml(CP)* respectively. Jewel appears to have additional resistance, possibly non-specific. Of the spring barley candidates, Extract possesses specific resistance, perhaps including *Mla9*, while Chalice, Ferment and Livet probably carry *mlo*.

DISCUSSION

The 1997 survey revealed no major changes in the barley mildew population. The resistance factors in current cultivars are all matched by corresponding virulence in the population, with the exception of *mlo*. Most of these virulences, and some currently not under selection, occur at high frequencies. The pathotypes detected in 1997 were similar to those identified in previous years. The barley mildew population is very diverse, made up of a large number of complex pathotypes. Although all the resistance factors in current use, except *mlo*, are mainly ineffective, many winter cultivars have good levels of non-specific resistance.

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MILDEW OF BARLEY IN NORTHERN IRELAND

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Only 12 isolates were tested, but seven new single virulence differential cultivars were introduced. Frequencies of most virulences have remained at similar levels to previous seasons - the frequency of the combined virulence *Vla, Va13*, which increased dramatically in the previous season, has remained relatively high, although there is now no cultivar being grown carrying either gene. Comparison with results from Britain over the years 1990-96 showed good correlation of overall means of virulence frequencies, but a poor correlation on trends of individual virulences.

INTRODUCTION

Due to a misunderstanding, only 12 isolates were collected in 1997, all from spring barley, 10 from Chad (*Ml(Ab), Mla1*) and 2 from Dandy (*mlo*). The number of test cultivars was, however, increased to 23 with the addition of seven new cultivars differentiating for a single major gene. Isolates were obtained using Golden Promise trap plants from which single pustules were grown up on further Golden Promise plants before being transferred to the differential cultivars. A list of all the cultivars used for testing virulences of isolates and their genetic designations, are shown in Table 2.

The most commonly sown cultivars in N. Ireland in the same season, 1996/97, are shown in Table 1. The cultivar Riviera increased dramatically over the previous season and now that it has been established that it is carrying the *mlo* gene, the % of cultivars with *mlo* stands at 82%. The winter barley area is dominated by Regina (*Mlra, Mla12*), a cultivar which did not appear on the list in the previous year. The popularity of Fighter and Pastoral have declined sharply.

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*)	63
Dandy (*mlo*)	27	Pastoral (*Mlra*)	17
Felicie (*Mlg, Ml(CP), Mla9*)	10	Hanna (*none*)	11
Chariot (*mlo*)	7	Fighter (*Mlg, Ml(CP), Ml(Ab)*)	5
Delibes (*Ml(Ab), Mla1*)	6	Manitou (*Mla9*)	3

Table 2 Test cultivars for the detection of virulence groups.

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

RESULTS

The frequencies of a range of single major genes and some of their combinations are shown in Table 3. Because of the relatively low number of isolates compared with previous seasons, figures are probably not so reliable. Nevertheless, values for the new differentials testing for *Vh*, *Vra*, *Vk1* and *Va7* proved to be similar to those obtained in Britain (Slater & Clarkson, 1998). The value for *Va3* was somewhat higher, but another season's figures are probably required before a meaningful comparison can be made. Testing for virulence to *mlo* alone using Apex did show a small percentage, but in the past there have been occasional pustules on the other differential carrying *mlo*, Atem, which did not prove capable of transference, although this was not tested in this instance. Values for remaining virulences were generally higher than in the previous season (Mercer, 1997) although mostly within the general range of variation. The combined virulence *Vla, Va13* which increased dramatically in the previous season has remained at this relatively high level. Values for *V(Ab)*, *Va1* and *Va7, V(Ab)* are probably unreliable as only two isolates were non-corresponding.

Table 3 Frequencies of virulence alleles from isolates collected from barley crops from 1990 to 1997.

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

* only two isolates

Earlier in the year, an analysis was made of trends in the levels of single virulence genes in N. Ireland compared with Britain and these are included below. Comparisons were made for the years 1990 - 96 with published results from the United Kingdom Cereal Pathogen Virulence Survey Reports, 1991 - 1997 and show (Table 4) a good correlation between means for the whole period ($r^2 = 0.93$). However, the correlation in trends for individual virulences was relatively poor, the highest being with *Va9* ($r^2 = 0.72$) and *Va12* ($r^2 = 0.40$).

Table 4 Comparison of frequencies of selected virulences in N. Ireland and England from 1990 - 1996

Virulence	Area	1990	1991	1992	1993	1994	1995	1996	Mean
Va6	NI	41	54	36	47	56	26	41	43
Va6	England	11	28	20	47	35	35	36	30
VLa	NI	27	57	25	47	42	44	33	39
VLa	England	14	35	34	25	29	26	58	32
Va12	NI	46	54	31	67	74	61	80	59
Va12	England	41	67	76	83	78	79	75	71
Va1	NI	20	14	14	40	22	41	7	23
Va1	England	14	8	9	18	22	17	47	19
Va9	NI	27	30	28	30	29	46	45	34
Va9	England	14	20	28	29	27	31	38	27
Va13	NI	14	46	25	27	37	19	38	33
Va13	England	12	16	32	22	28	31	36	25

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YELLOW RUST OF BARLEY

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No samples were received in 1997. Seedling and adult plant tests provided more information on the susceptibility/resistance of current cultivars. Susceptible cultivars will comprise approximately 35% of the winter and 13% of the spring barley acreage in 1998, thus greatly increasing the risk of this disease returning to barley crops. Fortunately, resistant cultivars are available, but variety diversification is needed to reduce selection pressure on the pathogen population.

1997 ISOLATES

No samples were received in 1997.

VIRULENCE FREQUENCIES FOR 1982-1997

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 1982-97 are given in Table 2.

Table 2 Virulence factor frequency (%)

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

† Not included in tests before 1983.

SEEDLING AND ADULT PLANT VIRULENCE TESTS

Methods

Seedlings of 19 spring barley cultivars were inoculated with five isolates of *Puccinia striiformis* (Table 3) in seedling tests (incubated under a regime of 8 hours at 10°C / 16 hours at 18°C), and in adult plant spreader beds in the field.

Table 3 Isolates of *Puccinia striiformis* used in comparative seedling and adult plant tests

Isolate	Source		BYV
code	Cultivar	Location	Factors
74/33	Malta	Northumberland	0
75/101	Varunda	Yorkshire	1,2
80/47	Erna	Northumberland	1,2
82/13	Igri	Scotland	1
83/39	Tasman	W. Midlands	1,2,3

Results

Results are given in Table 4.

Cultivar x isolate interactions were apparent in seedling tests, indicating the presence of specific resistance factors in certain culativars. However, these interactions were rarely mirrored at the adult plant stage. Isolate 83/39 (BYV 1,2,3) was generally more aggressive than the other isolates, giving increased levels of infection on most cultivars, irrespective of their seedling specific resistance.

Discussion

Estimates of the proportion of the barley acreage occupied by cultivars with different levels of resistance to yellow rust are given in Tables 5 and 6.

For winter barley, nearly 20% of the acreage is now occupied by highly susceptible cultivars with ratings of 2. This represents a serious risk of epidemic development, despite the fact that yellow rust has virtually disappeared from the barley crop over the past few years. The picture in spring barley gives less cause for concern, as no commercial cultivar has a rating below 4 and nearly 70 % of the acreage consists of highly resistant cultivars with ratings of 8 or 9.

Table 4. % yellow rust infection on adult plants in spreader bed tests (mean of 5 assessments) and seedling reaction type (R = 0-2, I = 2.1-2.9, S = 3-4)

Cultivar	BYR Factor	74/33 (BYV 0)		82/13 (BYV 1)		75/101 (BYV 1,2)		80/47 (BYV 1,2)		83/39 (BYV 1,2,3	
Atem	1	1.4	R	2.7	S	1.1	S	1.9	S	3.1	S
Mazurka	2	3.5	R	3.7	R	16.2	S	4.0	R	15.9	S
Varunda	2	2.7	R	1.7	R	2.3	S	1.2	S	9.8	S
Triumph	3	1.2	R	1.4	R	1.3	R	1.5	R	4.6	S
Chalice	0	1.3	S	1.0	S	1.4	S	2.0	S	1.7	S
Chariot	0	1.5	S	1.0	S	1.3	S	1.2	S	2.9	S
Extract	0	4.0	S	5.7	S	3.2	S	6.5	S	14.9	S
Felicie	0	3.4	S	5.4	S	2.5	S	3.9	S	9.4	S
Dandy	1	1.3	R	0.9	S	0.9	S	1.7	S	1.4	S
Hart	1	4.1	R	3.7	S	3.0	S	8.0	S	4.8	S
Riviera	1	1.5	R	8.5	S	1.5	I	3.6	S	15.8	S
Alexis	3	3.7	R	6.1	R	3.8	R	4.4	R	14.5	S
Prisma	3	1.2	R	1.6	R	0.9	R	1.5	R	4.1	S
Landlord	Rx	2.7	S	3.9	S	2.8	R	3.0	S	3.9	S
Tankard	Rx	2.5	S	3.7	S	2.5	R	3.6	S	7.9	S
Cooper	Rx	1.3	R	2.4	R	0.6	R	2.6	S	3.9	S
Optic	Rx	2.5	R	1.4	R	0.9	R	1.6	S	1.7	R
Delibes	R	0.9	R	0.9	R	0.7	R	0.7	R	1.3	R
Derkado	R	0.9	R	0.8	R	1.1	R	1.0	R	1.5	R

Table 5 Estimated % of the winter barley acreage of England and Wales occupied by cultivars with different yellow rust resistance ratings in 1998 (from seed production statistics).

Cultivar	1-9 rating	% acreage
Angora	2	2.1
Melanie	2	3.0
Regina	2	14.8
Muscat	4	3.0
Intro	5	11.6
Linnet	5	0.5
Manitou	5	0.2
Gaelic	6	1.2
Hanna	6	3.0
Fanfare	7	13.7
Fighter	7	8.6
Halcyon	7	7.5
Pipkin	7	3.1
Epic	8	0.4
Gleam	8	11.2
Pastoral	8	5.1
Puffin	8	2.1
Rifle	8	4.9

Disease resistance ratings
1,2,3 = very susceptible
4,5 = susceptible
6,7 = moderately resistant
8,9 = resistant

Table 6 Estimated % of the spring barley acreage of England and Wales occupied by cultivars with different yellow rust resistance ratings in 1998 (from seed production statistics).

Cultivar	1-9 rating	% acreage
Felicie	4	0.5
Riviera	4	1.3
Alexis	5	3.8
Hart	5	7.3
Cooper	6	4.3
Landlord	6	1.0
Tankard	7	0.2
Chariot	8	31.3
Delibes	8	1.7
Derkardo	8	1.2
Optic	8	37.9
Prisma	8	0.6
Dandy	9	2.3

Disease resistance rating
1,2,3 = very susceptible
4,5 = susceptible
6,7 = moderately resistant
8,9 = resistant

BROWN RUST OF BARLEY

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Virulences corresponding to all the specific resistances carried by the differential cultivars with the exception of Cebada Capa (BBR-7) were identified in the 1997 isolates. A number of spring barleys which displayed higher levels of brown rust in 1996 than expected were resistant in adult plant field nurseries; the high levels of disease displayed were of a mainly resistant infection type. Glasshouse tests identified the majority of currently recommended NIAB spring barleys and some of the winter barleys as carrying effective adult plant resistance.

GLASSHOUSE SEEDLING TESTS WITH 1997 ISOLATES

Twelve of the forty-one barley brown rust samples received in 1997 were collected from spring barley cultivars. The remainder were from a range of winter barleys which included fourteen from a single trial site. The geographic origins of the samples are given in Table 1.

Table 1 Geographical origin of 1997 barley brown rust samples

Location (MAFF region)	Number of samples
North	25
Yorkshire and Humberside	2
West Midlands	6
East Midlands	1
South East	3
South West	3
Wales	1

Isolates of *Puccinia hordei* Otth. were cultured from thirty-three of the samples and tested on a set of ten differential cultivars (Table 2).

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

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

Results

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

Table 3 Races identified from 1997 isolates

Number of isolates	Octal designation	BBV factors
2	273	1,2,4,5,6,8
1	277	1,2,3,4,5,6,8
1	673	1,2,4,5,6,8,9
8	1273	1,2,4,5,6,8,10
6	1277	1,2,3,4,5,6,8,10
3	1653	1,2,4,6,8,9,10
1	1657	1,2,3,4,5,8,9,10
9	1673	1,2,4,5,6,8,9,10
2	1677	1,2,3,4,5,6,8,9,10

The virulence combinations gave a range from six virulence factors in two isolates to the widely virulent race octal 1677, also found in two isolates, which carries virulence to all the differential cultivars with the exception of cv. Cebada Capa (BBR-7). This is the only differential cultivar to which virulence has not been identified in the UK pathogen population.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Following the concern in 1996 that the resistances of some spring barley cultivars, especially derivatives of cv. Chariot, were becoming less effective, adult plants were tested in the glasshouse with isolates cultured from two of these cultivars. Data from these tests suggested that virulence to some cultivars may be increasing, so in 1997 spring barley nurseries were sown to test these isolates under field conditions.

Twenty eight cultivars were sown in each of two nurseries in the spring of 1997. The nurseries were each inoculated with one or other of the following isolates of *Puccinia hordei*.

Isolate	Origin
BRS-96-5 (BBV-1,2,4,5,6,8)	cv. Draught, Shropshire
BRS-96-6 (BBV-1,2,3,4,5,6,8,9,10)	cv. Landlord, Shropshire

Results

These are summarised in Table 4. Good levels of infection built up on the susceptible cultivars within both nurseries with the isolates differentiating the resistances of some of the cultivars. Cultivars are classified into groups on the basis of their responses to the two isolates introduced into the nurseries.

Group 1: Highly susceptible to both isolates.

Group 2: Cultivars Simon (BBR-3) and Triumph (BBR-10) were susceptible to isolate BRS-96-6 which carries the corresponding virulences BBV-3 and BBV-10. Cultivars Cork, Prisma and Alexis also showed a similar pattern of responses to the isolates, though in the absence of an isolate in these tests to differentiate between cultivars carrying BBR-3 and BBR-10 their resistances cannot be confirmed. Glasshouse tests in previous years have suggested that cv. Prisma carries BBR-10, whilst cvs Alexis and Charm may carry BBR-3.

Group 3: Included within this group are cv. Chariot and a number of its derivatives reported to have been showing higher levels of disease than expected in 1996. They had expressed a mixed, mainly resistant response to both isolates as adult plants in 1996 glasshouse tests (Jones and Clifford, 1997). In these field tests they showed generally high levels of infection in both nurseries, this again being of a mixed, mainly resistant type to isolate BRS-96-5 but of a resistant type only to isolate BRS-96-6.

Group 4: Cultivar Felicie responded similarly to the isolates as cv. Vada which carries a non-specific resistance.

Group 5: Quantitative levels of disease on cultivars within this group were generally lower, especially to isolate BRS-96-5, than those observed on cultivars classified in previous groups. With the exception of cvs Optic and Charm, which showed a mixed, mainly resistant reaction to isolate BRS-96-6, the cultivars in Group 5 expressed resistance.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF BROWN RUST

Adult Plant Tests

Spring and winter barleys were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with one each of the following isolates:

Isolate	Origin
BRS-96-6 (BBV-1,2,3,4,5,6,8,9,10)	cv. Draught, Shropshire
BRS-97-41 (BBV-1,2,4,5,6,8,10)	cv. Chalice, Wales
BRS-97-13 (BBV-1,2,4,5,6,8)	cv. Peridot, Northumberland

The plants were inoculated as described previously (Jones and Clifford, 1996). Assessment was made of the infection type on the flag leaf. These were classified on the standard 0-4 scale as resistant (R = 0-2) or susceptible (S = 3-4).

Seedling Tests

Seedlings of the cultivars, grown to the second leaf stage, were inoculated with the same isolates under the same conditions as the adult plants. These were also assessed in the same way.

Results

The winter barley cultivars (Table 5) were susceptible as seedlings to the three isolates. On the basis of similarities in their pattern of adult plant responses to the isolates the cultivars were classified into groups.

Group 1: Cultivars susceptible.

Group 2: The adult plant resistances of these cultivars were effective to all but isolate BRS-97-41 which was cultured from infected leaves of cv. Chalice grown in a field nursery at IGER. Their resistance was not, however, overcome by isolate BRS-96-6 which carries virulences in addition to those carried by BRS-97-41.

Group 3: These cultivars carry additional adult plant resistance to the isolates against which they were tested.

The responses of the spring barley cultivars to the isolates are given in Table 6.

Group 1: Cultivars susceptible.

Group 2: Isolate BRS-96-6 which, unlike the other isolates, carries BBR-3, overcame the resistance of the cultivars. Previous results have suggested that the cultivars within this group carry either BBR-3 or BBR-10 (Triumph). These results suggest they carry BBR-3, as BRS-97-41 which also carries BBR-10 failed to infect them.

Group 3: The adult plant resistance of these cultivars was effective to all but isolate BRS-97-41. They had been resistant (mixed reaction type) in the field nursery (Table 4) to isolate BRS-96-5 but showed a mainly susceptible response to isolate BRS-97-41 which was cultured from type 3 pustules on cv. Chalice grown in the nursery.

Group 4: These cultivars had shown a similar pattern of response to those in Group 3 to the isolates against which they had been tested in the 1997 field nurseries (Table 4). They differed in these tests, however, as they were classified as being resistant (mixed reaction type) to isolate BRS-97-41. This confirms their field response to isolate BRS-96-5 in the field nursery.

Group 5: The overall resistance of these cultivars was effective against isolates BRS-97-41 and BRS-97-13 but resistance was only expressed at the adult plant stage to isolate BRS-96-6. The cultivars had also, with the exception of cv. Tankard, expressed good levels of resistance in the field nursery.

Group 6: Cultivar Livet carries overall resistance effective against all three isolates.

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Table 4 Percent infection* of spring barley cultivars to specific isolates of *Puccinia hordei* in field isolation nurseries in 1997

Cultivar [NIAB rating]	Group	Isolate BRS-96-5 (BBV-1,2,4,5,6,8)		BRS-96-6 (BBV-1,2,3,4,5,6,8,9,10)	
Midas	1	43		43	
Dandy [4]		36		31	
Riviera [4]		29		33	
Hart [4]		28		29	
Simon (BBR-3)	2	1	MR	16	
Triumph (BBR-10)		9	MR	28	
Cork		8	MR	8	MS
Prisma [6]		18	MR	39	
Alexis [5]		19	MR	40	
Tyne [6]	3	13	MR	7	R
Extract [(8)]		17	MR	7	R
Tankard [7]		19	MR	16	R
Pitcher		24	MR	12	R
Trinity		24	MR	21	R
Landlord [6]		27	MR	25	R
Chalice [(6)]		28	MR	30	R
Draught		29	MR	20	R
Chariot [3]		26	MS	16	R
Vada	4	21	MR	14	MR
Felicie [5]		18	MR	15	MR
Optic [8]	5	0.5	R	6	MR
Charm		3	R	13	MR
Delibes [9]		Trace	R	6	R
Cooper [8]		2	R	6	R
Heron		4	R	7	R
Derkado [8]		7	R	16	R
Livet [(7)]		8	R	9	R
Ferment [(7)]		10	R	14	R

*Mean of 4 replicates, final 2 assessment dates
All reaction types susceptible unless stated
MS = mixed susceptible; MR = mixed resistant; R = resistant
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 5 Reactions* of winter barley cultivars (adult plant and seedling) to specific isolates of *Puccinia hordei* under glasshouse conditions

Isolate ... Cultivar [NIAB rating]	Group	BRS-97-13 (BBV-1,2,4,5,6,8)		BRS-96-6 (BBV-1,2,3,4,5,6,8,9,10)		BRS-97-41 (BBV-1,2,4,5,6,8,10)	
Angora [3]	1	S	(S)	S	(S)	S	(S)
Manitou [5]		S	(S)	S	(S)	S	(S)
Melanie [4]		S	(S)	S	(S)	S	(S)
Fighter [6]		S	(S)	S	(S)	S	(S)
Vertige [6]		S	(S)	S	(S)	S	(S)
Pipkin [6]		S	(S)	S	(S)	S	(S)
Pastoral [6]		S	(S)	S	(S)	S	(S)
Regina [6]		S	(S)	S	(S)	S	(S)
Gleam [7]		S	(S)	S	(S)	S	(S)
Fanfare [7]		S	(S)	S	(S)	S	(S)
Halcyon [7]		S	(S)	S	(S)	S	(S)
Muscat [7]		S	(S)	S	(S)	S	(S)
Linnet [8]		S	(S)	S	(S)	S	(S)
Gaelic [8]		MS	(S)	MS	(S)	MS	(S)
Epic [8]	2	R	(S)	R	(S)	S	(S)
Hanna [7]		R	(S)	R	(S)	S	(S)
Baton [8]		R	(S)	R	(S)	MS	(S)
Peridot [9]		R	(S)	R	(S)	MS	(S)
Intro [8]		MR	(S)	R	(S)	MS	(S)
Spirit [7]	3	MR	(S)	R	(S)	MR	(S)
Rifle [9]		R	(S)	R	(S)	MR	(S)
Jewel [8]		R	(S)	R	(S)	MR	(S)
Puffin [8]		R	(S)	R	(S)	R	(S)

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

Seedlings assessed on 1st leaf. Adult plant assessed on flag leaf
( ) = seedling reaction
[ ] NIAB rating: 1 = susceptible; 9 = resistant

Table 6 Reactions* of spring barley cultivars (adult plant and seedling) to specific isolates of *Puccinia hordei* under glasshouse conditions

Isolate ... Cultivar [NIAB rating]	Group	BRS-97-13 (BBV-1,2,4,5,6,8)		BRS-96-6 (BBV-1,2,3,4,5,6,8,9,10)		BRS-97-41 (BBV-1,2,4,5,6,8,10)	
Hart [4]	1	S	(S)	S	(S)	S	(S)
Dandy [4]		S	(S)	S	(S)	S	(S)
Riviera [4]		S	(S)	S	(S)	S	(S)
Alexis [5]	2	R	(R)	S	(S)	R	(MR)
Cork		R	(R)	MS	(S)	R	(MS)
Prisma [6]		R	(R)	MS	(S)	R	(MR)
Simon (BBR-3)		R	(MR)	S	(S)	R	(MR)
Draught	3	MR	(S)	R	(S)	S	(S)
Pitcher		MR	(S)	R	(S)	MS	(S)
Chalice [(6)]		R	(S)	R	(S)	MS	(S)
Trinity		R	(S)	R	(S)	MS	(MS)
Chariot [3]	4	R	(S)	R	(S)	MR	(S)
Felicie [5]		R	(S)	R	(S)	MR	(S)
Tyne [6]		R	(S)	R	(S)	MR	(S)
Landlord [(6)]		R	(MS)	R	(S)	MR	(MS)
Cooper [8]		R	(MS)	R	(MS)	R	(MS)
Extract [8]		R	(MS)	R	(MS)	R	(MS)
Tankard [7]	5	MR	(R)	R	(MS)	MR	(MR)
Charm		R	(R)	R	(S)	MR	(R)
Optic [8]		R	(R)	R	(S)	R	(MR)
Delibes [9]		R	(R)	R	(S)	R	(MR)
Derkado [8]		R	(R)	R	(MS)	R	(R)
Ferment [(7)]		R	(R)	R	(MS)	R	(MR)
Toddy		R	(R)	R	(S)	MR	(MS)
Livet [(7)]	6	R	(R)	R	(MR)	R	(R)

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

Seedlings assessed on 1st leaf. Adult plant assessed on flag leaf
( ) = seedling reaction
[ ] NIAB rating: 1 = susceptible; 9 = resistant

RHYNCHOSPORIUM OF BARLEY

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1997 isolates were generally less widely virulent than in recent years with virulence to a number of the differential cultivars at a reduced frequency. Glasshouse tests confirmed a number of the winter barleys as carrying a specific resistance (BRR-2). Of the spring barleys, cv. Ferment is thought to carry the resistance factor BRR-1 and cv. Livet the resistance factor BRR-8.

SEEDLING TESTS WITH 1997 ISOLATES

Leaf samples of *Rhynchosporium secalis* were received from a range of winter (50) and spring (32) barley cultivars. An additional two samples were of unknown cultivar origin. The geographic origins of the eighty-four samples are given in Table 1.

Table 1 Geographic origin of *Rhynchosporium* samples received in 1997

Location (MAFF Region)	Number of samples
Scotland	49
North	10
South-west	9
West Midlands	6
South-east	4
East Midlands	3
East Anglia	2
Yorkshire and Humberside	1

Isolates were successfully cultured from forty-five of the samples and tested on a set of differential cultivars which included cv. Digger. This spring barley has shown high levels of resistance, as a seedling and as an adult plant, to all but a few of the survey isolates to which it has been tested in recent years. The isolate:differential cultivar interactions indicate that the resistance carried by cv. Digger is different to that of the other differential cultivars. Test cultivars and their resistance factors are given in Table 2.

Table 2 Differential test cultivars for *Rhynchosporium secalis*

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

Results

A range of virulence combinations were identified from the isolates when classified on the set of differential cultivars (Table 3).

Table 3 Virulence factor combinations identified from the 1997 isolates

No. of isolates	Differential cultivars in linear order								Race octal
	Digger	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
2	0	0	0	0	0	1	0	0	4
13	0	0	0	0	1	1	0	0	14
4	0	1	0	0	1	1	0	0	114
1	1	1	0	0	1	1	0	0	214
11	0	1	1	1	1	1	0	0	174
13	0	0	0	0	1	1	1	1	17
1	0	1	0	0	1	1	1	1	117

1 = susceptible 0 = resistant

Virulences compatible with the resistances conferred by cv. La Mesita (BRR-5) and cv. Osiris (BRR-6) were found in only one isolate, RS-97-65 (race octal 174) cultured from an infected leaf sample of cv. Chariot.

Cultivar Digger (BRR-8) was susceptible only to isolate RS-97-31 (race octal 214) cultured from a sample of Hanna grown in Aberdeenshire.

The reduced frequency of virulence to cv. La Mesita (Table 4) in the 1997 isolates was probably a consequence of no samples being received from cv. Pipkin which is one of the few commercially grown cultivars known to carry the same resistance, BRR-5. Consequently virulence to cv. Osiris (BRR-6) was also at a reduced frequency as this virulence is often found in combination with BRR-5 (Jones and Clifford, 1997).

Table 4 Frequencies of individual virulences, 1988-1997

	BRV-								No. of isolates
	8	7	6	5	4	3	2	1	
1988	-	0.81	0	0	0.98	0.98	0.19	0.19	48
1989	-	0.54	0.08	0.23	0.92	0.92	0.62	0.62	15
1990	-	0.54	0.23	0.30	0.76	0.92	0.23	0.23	13
1991	-	0.28	0	0	0.52	0.74	0.22	0.22	50
1992	-	0.50	0.07	0.10	0.86	0.97	0.40	0.40	30
1993	-	0.57	0.07	0.12	0.94	1.00	0.68	0.68	69
1994	-	0.85	0.07	0.15	0.97	0.99	0.88	0.88	67
1995	-	0.26	0.13	0.30	0.65	0.91	0.26	0.26	23
1996	-	0.68	0.18	0.39	0.71	1.00	0.61	0.61	28
1997	0.02	0.37	0.02	0.02	0.96	1.00	0.31	0.31	45

The reduced frequency of virulence to cvs Armelle (BRR-1) and Astrix (BRR-2) compared to 1996 is probably at least partly due to a lower proportion of isolates tested being cultured from winter cultivars in 1997 (62%) than in 1996 (86%); several of the currently recommended winter barley cultivars carry resistance factor (BRR-2) (see Table 5, Glasshouse Tests). None of the currently recommended spring barleys have been identified as carrying either BRR-1 or BRR-2 so isolates cultured from infected leaf samples of these do not need to carry the corresponding virulences.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF *RHYNCHOSPORIUM*

Adult Plant Tests

Twenty-seven winter and twenty-eight spring barleys were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with one of each of the following isolates.

Isolate	Race octal	BRV
RS-97-52 (ex Intro)	117	1,2,3,4,7
RS-97-65 (ex Chariot)	174	3,4,5,6,7
RS-97-31 (ex Hanna)	214	3,4,7,8

The plants were inoculated by spraying with a fresh spore suspension, placed in dew 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 the area of flag leaves infected 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 isolates and incubated under the same conditions as the adult plants. Seedlings were assessed on infection levels on the second leaf and classified on the same 0-9 scale.

Results

Seedling and adult plant test results are given in Table 5 (winters) and Table 6 (springs). Cultivars are grouped within the tables primarily on the basis of similarities in the patterns of their adult plant responses to the isolates but it should not be interpreted that cultivars within a group carry a common resistance factor(s).

Winter barleys (Table 5)

Group 1: Cultivars were generally susceptible although the responses of seedlings of some of the cultivars were classified as resistant. Isolates carrying virulence factors in different combinations to those tested in 1997 have previously differentiated some of the cultivars within the group.

Group 2: These cultivars were susceptible as adult plants and seedlings, to isolate RS-97-63 (race octal 117) only, confirming previous years' data from adult plant and/or seedling tests that they carry resistance factors BRR-1 or BRR-2.

Group 3: Cultivar Pipkin (BRR-5) was susceptible as an adult plant and as a seedling to RS-97-65 (race octal 174) which was the only isolate in these tests to carry the corresponding virulence BRV-5. It was also classified as susceptible in adult plant tests to isolate RS-97-63 and this confirms previous observations (Jones and Clifford, 1982) that cv. Pipkin, like cv. La Mesita, from which it derives its resistance, is more susceptible at the adult plant stage of growth, even to isolates not carrying the corresponding virulence gene.

Group 4: Cultivar Manitou which has previously shown good levels of resistance, particularly at later growth stages, was susceptible to isolate RS-97-31 (race octal 214).

Spring barleys (Table 6)

Group 1: The majority of the spring barley cultivars were susceptible to the three isolates. Cultivar Toddy which had been seedling resistant to race octal 0 in the 1996 tests was also resistant as a seedling to isolate RS-97-31 (race octal 214) as was cv. Landlord.

Group 2: The resistance of cv. Armelle (BRR-1) was effective against the isolates not carrying the corresponding virulence factor (BRV-1). The responses of cv. Ferment to the isolates suggests that it too carries BRR-1.

Group 3: Cultivar La Mesita (BRR-5) was infected as an adult plant by isolates RS-97-63 and RS-97-31 which do not carry the corresponding virulence (BRV-5) but it was more heavily infected by isolate RS-97-65 which does.

Group 4: The specific overall resistance of cv. Osiris (BRR-6) was overcome by isolate RS-97-65 (race octal 174).

Group 5: Cultivar Digger (BRR-8) was susceptible as an adult plant to isolate RS-97-31 (race octal 214) only. Isolate RS-97-65 also induced infection on seedlings of this cultivar but failed to infect it at later growth stages. Seedling tests in 1996 suggested that cv. Livet may carry a resistance in common with cv. Digger. Data from 1997 tests substantiate this.

ADULT PLANT FIELD NURSERIES

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

Results

Assessment of percentage infection levels were made and results are given in Table 7. Good levels of disease were achieved on the susceptible cultivars with a range of quantitative responses being displayed. Resistance was expressed by all the differential cultivars including cv. La Mesita which is susceptible at later growth stages to the majority of isolates against which it is tested, including those which are not identified as carrying the corresponding virulence factor in seedling tests. Isolates cultured from infected leaves sampled from the nursery were identified as race octal 14, which carries virulence to the winter differential cultivars Athene (BRR-3) and Igri (BRR-4).

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

Cultivar [NIAB rating]	Group	RS-97-63 (Race octal 117) BRV-1,2,3,4,7		RS-97-65 (Race octal 174) BRV-3,4,5,6,7		RS-97-31 (Race octal 214) BRV-3,4,7,8	
Maris Otter	1	9	(9)	9	(9)	9	(9)
Puffin [6]		9	(9)	9	(8)	9	(9)
Rifle [6]		9	(5)	7	(5)	9	(7)
Fanfare [8]		9	(8)	7	(7)	8	(6)
Athene (BRR-3)		9	(7)	7	(7)	8	(6)
Muscat [7]		9	(9)	5	(5)	8	(5)
Jewel [8]		9	(8)	8	(8)	6	(8)
Epic [5]		9	(7)	5	(4)	6	(3)
Gaelic [5]		8	(9)	8	(9)	7	(6)
Pastoral [7]		8	(8)	8	(8)	5	(8)
Igri (BRR-4)		8	(8)	8	(8)	5	(8)
Fighter [6]		8	(8)	7	(5)	5	(8)
Peridot [5]		7	(7)	9	(4)	8	(6)
Vertige [5]		7	(8)	5	(3)	6	(4)
Pirate (BRR-7)		8	(9)	5	(6)	5	(6)
Melanie [8]	2	9	(8)	0	(0)	0	(0)
Baton [7]		9	(9)	0	(0)	0	(2)
Intro [5]		9	(6)	0	(0)	0	(0)
Gleam [7]		8	(7)	0	(0)	0	(0)
Regina [7]		8	(9)	0	(0)	0	(0)
Angora [7]		8	(9)	0	(0)	0	(0)
Astrix (BRR-2)		8	(7)	0	(0)	0	(1)
Halcyon [5]		8	(8)	0	(2)	0	(0)
Hanna [8]		8	(7)	4	(2)	2	(0)
Spirit [8]		6	(7)	0	(0)	3	(0)
Pipkin [3]	3	5	(0)	9	(6)	2	(1)
Manitou [8]	4	0	(1)	2	(5)	6	(6)

* Assessments of leaf area infected on a 0-9 scale (mean of 2 plants)

Resistant: 0-4, Susceptible: 5-9

( ) seedling reaction

[ ] 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 [NIAB rating]		Group	RS-97-63 (Race octal 117) BRV-1,2,3,4,7		RS-97-65 (Race octal 174) BRV-3,4,5,6,7		RS-97-31 (Race octal 214) BRV-3,4,7,8	
Alexis	[4]	1	9	(9)	9	(9)	9	(8)
Chariot	[3]		9	(7)	9	(8)	9	(7)
Tankard	[3]		9	(9)	9	(9)	9	(9)
Hart	[5]		9	(9)	9	(9)	9	(9)
Derkado	[3]		9	(7)	8	(8)	9	(6)
Optic	[4]		8	(8)	9	(9)	9	(8)
Cooper	[6]		8	(7)	9	(7)	8	(6)
Cork			8	(7)	8	(8)	9	(7)
Riviera	[5]		7	(8)	9	(9)	9	(9)
Delibes	[7]		7	(8)	9	(9)	9	(8)
Felicie	[7]		8	(8)	8	(9)	9	(9)
Tyne	[6]		8	(7)	8	(9)	8	(7)
Prisma	[7]		9	(9)	9	(9)	7	(7)
Draught			8	(8)	9	(9)	8	(8)
Charm			8	(9)	9	(9)	6	(9)
Trinity			8	(7)	9	(8)	7	(8)
Pitcher			8	(6)	9	(9)	9	(7)
Chalice	[5]		9	(8)	9	(9)	7	(9)
Extract	[6]		7	(8)	8	(7)	6	(5)
Toddy			8	(8)	8	(6)	7	(4)
Dandy	[7]		7	(7)	7	(7)	7	(7)
Landlord	[7]		7	(8)	6	(6)	8	(4)
Armelle	(BRR-1)	2	8	(9)	0	(0)	0	(0)
Ferment	[8]		8	(7)	1	(1)	0	(2)
La Mesita	(BRR-5)	3	6	(1)	9	(9)	2	(0)
Osiris	(BRR-6)	4	0	(0)	9	(8)	1	(0)
Digger	(BRR-8)	5	0	(0)	0	(5)	8	(9)
Livet	[8]		0	(0)	0	(3)	7	(7)

* Assessments of leaf area infected on a 0-9 scale (mean of 2 plants)

Resistant: 0-4, Susceptible: 5-9

( ) seedling reaction

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

Table 7 Infection of spring barley cultivars in the SCRI *Rhynchosporium* nursery in 1997

Cultivar [NIAB rating]		Mean % infection
Cooper	[6]	34.0
Derkado	[3]	33.4
Optic	[4]	31.8
Tankard	[3]	29.7
Prisma	[7]	19.0
Chariot	[3]	18.5
Alexis	[4]	17.8
Landlord	[7]	15.6
Tyne	[6]	14.0
Delibes	[7]	11.2
Hart	[5]	9.1
Riviera	[5]	7.3
Felicie	[7]	7.0
Dandy	[7]	4.4
Osiris	(BRR-6)	0.8
La Mesita	(BRR-5)	0.2
Digger	(BRR-8)	0.1
Athene	(BRR-3)	0.1
Igri	(BRR-4)	0.1
Armelle	(BRR-1)	0.05
Pirate	(BRR-7)	0.03
Astrix	(BRR-2)	0.01
SED		5.19

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

NET BLOTCH OF BARLEY

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Isolates obtained from the high number of samples received in 1997 identified virulences, in various combinations, to all of the differential cultivars. The majority of the currently recommended winter and spring barley cultivars were susceptible as seedlings and adult plants to a specific isolate of the pathogen under glasshouse conditions.

GLASSHOUSE SEEDLING TESTS WITH 1997 ISOLATES

One hundred and fifty-eight samples of net blotch were received, of which 150 were from a range of winter barley cultivars with the remainder coming from spring barleys. Seventy-three of the samples were received from 3 trial sites. The geographic origins of the samples are given in Table 1.

Table 1 Geographic origins of net blotch samples received in 1997

Location (MAFF Region)	Number of samples
Yorkshire and Humberside	34
North	29
West Midlands	25
South East	26
South West	15
East Midlands	13
East Anglia	15
Scotland	1

The large number of samples prevented the culturing and testing of each of them. Seventy samples were selected on the basis of their geographic and cultivar origins and isolates obtained from these were tested on a set of 13 differential cultivars.

Results

Virulences compatible with the resistance factors in all 13 of the differential cultivars were identified but the frequency at which they occurred varied greatly between cultivars (Table 2).

Table 2 Virulence frequencies (%) corresponding to each differential cultivar (UKCPV Surveys, 1992-1997).

Code Number	Cultivar	1992	1993	1994	1995	1996	1997
1	C.I.5401	0	0	0	0	9	9
2	C.I.6311	2	0	14	13	21	13
3	C.I.9820	0	0	3	6	9	6
4	C.I.739	13	0	14	38	51	46
5	C.I.1243	9	0	23	13	48	46
6	C.I.4795	4	0	6	9	35	17
7	C.I.4502	4	0	11	0	21	19
8	C.I.4979	4	0	29	44	34	26
9	Proctor	52	43	97	88	92	93
10	Code 65(W)	9	100	3	16	35	20
11	C.I.9518(W)	56	29	100	100	95	100
12	Tenn.61-119(W)	50	0	69	50	88	81
13	C.I.9214	4	0	3	9	32	23
No. of isolates tested		46	7	35	32	85	70

W = winter cv.

Virulences to the majority of the cultivars were at similar frequencies to those seen in 1996 when they were at generally higher levels than for a number of years. The virulences identified occurred in 28 varying combinations in the different isolates. The virulence combinations which are based on the differential code numbers (Table 2) gave a range from two virulence factors (9,11) in eight isolates, to one isolate carrying virulence to all the differential cultivars. The most common combination was 9,11,12 found in twenty isolates.

As in 1996 there were reports of a high incidence of the disease which was reflected in the high number of samples received which again probably contributed to the wide range of virulence combinations identified.

GLASSHOUSE TESTS WITH A SPECIFIC ISOLATE OF NET BLOTCH

Adult Plant Tests:

Twenty-six winter and 32 spring barley cultivars, which included the standard differential set, were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with isolate BNS-97-85 which was cultured from a leaf sample of cv. Sunrise grown at a NIAB trial site in Shropshire. Seedling tests identified it as carrying virulence factors 4,5,9,10,11,12.

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

Seedlings:

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

Results

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

Winter barleys: The majority of the cultivars were classified as susceptible as adult plants (Table 3). Cultivars Pipkin and Regina were resistant, as they had been in similar tests the previous two years. All the cultivars were seedling susceptible. The three winter differential cultivars C.I.9518, Tennessee 61-119 and Code 65 were susceptible.

Spring barleys: Although cultivar rankings (Table 4) generally confirm those of 1995 and 1996 tests, the cultivars were generally more heavily infected in this test. This means that several cultivars which had previously been assessed as being resistant were now classified as susceptible. Of the cultivars on the current NIAB Recommended List of spring barleys only cv. Chariot was resistant, this resistance being expressed at the adult plant stage only. The differential cultivars C.I.1243 and Proctor were susceptible at both growth stages. The remainder of the differential cultivars were resistant with the exception of C.I.739 which was seedling susceptible.

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Table 3 Reactions of winter barley cultivars (adult plants and seedlings) to a specific isolate of net blotch under glasshouse conditions

Isolate	BNS-97-85 (BNV-4,5,9,10,11,12)	
Cultivar [NIAB Rating]	Adult plant reaction*	Seedling reaction†
Puffin [4]	8	4
Melanie [4]	8	4
Gleam [5]	7	4
Spirit [6]	7	4
Peridot [6]	7	4
Jewel [6]	7	4
Epic [8]	7	4
Manitou [4]	6	4
Angora [5]	6	3
Muscat [7]	6	3
Baton [7]	6	4
Linnet [7]	6	4
Gaelic [8]	6	3
Rifle [8]	6	3
Hanna [7]	5	3
Fighter [7]	5	4
Fanfare [8]	5	4
Intro [8]	5	3
Halcyon [7]	4	3
Pipkin [8]	4	4
Pastoral [8]	4	3
Regina [8]	2	3
Vertige [9]	2	3
C.I.9518	7	4
Tenn.61-119	5	4
Code 65	5	3

* = 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 4 Reactions of spring barley cultivars (adult plants and seedlings) to a specific isolate of net blotch under glasshouse conditions

Isolate	BNS-97-85 (BNV-4,5,9,10,12)	
Cultivar	Adult plant reaction*	Seedling reaction†
Prisma	9	4
Optic	8	4
Cooper	8	4
Landlord	8	4
Ferment	7	4
Alexis	7	4
Charm	6	3
Tankard	6	3
Extract	6	3
Tyne	6	3
Pitcher	6	3
Dandy	6	4
Toddy	6	4
Livet	6	3
Derkado	5	4
Draught	5	3
Felicie	5	3
Riviera	5	3
Delibes	5	3
Trinity	5	3
Cork	5	4
Chariot	4	3
C.I.5401	1	2
C.I.6311	2	2
C.I.9820	4	3
C.I.739	3	3
C.I.1243	5	3
C.I.4795	3	2
C.I.4502	1	2
C.I.4979	3	2
Proctor	6	4
C.I.9214	4	2

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

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

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

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Of 127 infected samples received in 1997, 47% contained barley mild mosaic virus (BaMMV) and 67% barley yellow mosaic virus (BaYMV). The most frequent combinations were BaYMV on Fighter and Intro (9 samples of each) and BaMMV on Puffin (11 samples). Six new outbreaks of resistance-breaking BaYMV were reported, bringing the UK total to 23.

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

127 positive samples were received in 1997. Most samples (67%) contained BaYMV and 47% had BaMMV (Table 1). In recent years, BaMMV has usually been the more frequent. For the 83 samples of which the cultivar is known, the most frequent combinations were BaYMV on Fighter and Intro (9 samples of each) and BaMMV on Puffin (11 samples). As in previous seasons, BaMMV predominated on malting cultivars with a Maris Otter parentage, but the linkage of malting quality and susceptibility to BaMMV may not hold on the newer cultivars (Fanfare, Melanie, Regina).

Table 1 Mosaic virus samples from 1997, classified by cultivar

Cultivar	BaMMV alone	BaYMV alone	Both viruses	Total samples
Angora	0	3	0	3
Epic^R	0	2	0	2
Fighter	2	6	3	11
Hanna	0	4	0	4
Intro	0	5	4	9
Linnet	0	3	0	3
Manitou	0	1	1	2
Muscat^R	0	4	0	4
Pastoral	1	5	1	7
Plaisant	0	3	0	3
Rifle	0	1	0	1
Feeding	3	37	9	49
Fanfare	1	3	0	4
Halcyon	5	0	0	5
Maris Otter	3	0	0	3
Melanie	0	2	0	2
Pipkin	1	0	0	1
Puffin	9	2	3	14
Regina	0	4	0	4
Spice	1	0	0	1
Malting	20	11	3	34
Unknown	19	19	6	44
TOTAL	42	67	18	127

^R indicates resistant (*ym4*) cultivar

The season was notable for six new outbreaks of resistance-breaking BaYMV, bringing the number of known UK sites to 23, scattered throughout the regions where winter barley has been grown most intensively (Table 2). While the dependence on *ym4* resistance continues, these outbreaks can only increase in number and size. Other sources of resistance (mostly from the Far East) are available to plant breeders (Graner *et al.*, 1995; Bauer *et al.*, 1997) but their stability in European conditions can only be determined if and when they become more widely used in popular cultivars.

Table 2 Origin of isolates of resistance-breaking barley yellow mosaic virus, 1988-1997

County	No.	County	No.
Beds	1	Essex	3
Berks	2	Glos	6
Bucks	1	Oxon	5
Cambs	3	Wilts	2

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MILDEW OF OATS

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Race 5 (OMV 1,2,3) was identified from all the isolates cultured from the 1997 samples. Glasshouse tests identified some of the currently NIAB recommended winter oat cultivars as carrying resistance effective at the adult plant stage only.

SEEDLING TESTS WITH 1997 ISOLATES

Twenty-six samples of oat mildew came from a range of spring oat cultivars. Of these, twenty-five came from two trial sites (Table 1). Isolates of *Erysiphe graminis avenae* were cultured from sixteen of the leaf samples and tested on a set of differential cultivars (Table 2).

Table 1 Geographic origins of oat mildew samples received in 1997

Location (MAFF Region)	Number of samples
North	
Cockle Park, Northumberland	12
Scotland	
Craibstone, Aberdeen	13
Wales	
Aberystwyth, Ceredigion	1

Table 2 Differential cultivars used for isolate testing

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

Results

All isolates were identified as race 5 (OMV-1,2,3), a widely virulent and common race carrying virulence to all the differential cultivars with the exception of cv. Cc 6490 (OMR-4). Resistance conferred by cv. Cc 6490 was effective to all the isolates although isolate OMS-97-6, cultured from a sample of cv. Sailor, induced some 3 type pustules on it.

GLASSHOUSE TESTS WITH A SPECIFIC ISOLATE OF OAT MILDEW

Adult Plant Tests

Spring and winter oats were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were exposed to mildew infected plants which had been inoculated with isolate OMS-97-2 (OMV-1,2,3), cultured from an infected leaf sample of cv. Piper.

Assessments were made of the area of flag leaves infected and of reaction type.

Seedling Tests

Seedlings of the same cultivars were exposed to the same isolate and were assessed on reaction type as being resistant (0-2) or susceptible (3-4).

Results

Seedling and adult plant test results are given in Table 3.

All the spring and winter oat cultivars were seedling susceptible but displayed a range of quantitative responses at later growth stages to the isolate. Some of the winter oat cultivars expressed good levels of adult plant resistance.

Table 3 Percent infection* of adult plant and seedling reactions of winter and spring oat cultivars to a specific isolate of *Erysiphe graminis avenae* under glasshouse conditions

Cultivar [NIAB rating]	Isolate OMS-97-6 (OMV-1,2,3)		
Winter oats			
Aintree [4]	22		(S)
Krypton [7]	18		(S)
Chamois [6]	15	MS	(S)
Harpoon [4]	10		(S)
Image [4]	12	MS	(S)
Jalna [6]	15	R	(S)
Emperor [7]	12	R	(S)
Solva [7]	5	R	(S)
Gerald [4]	1	R	(S)
Lexicon [7]	1	R	(S)
Spring oats			
Conny [4]	60		(S)
Amigo [6]	55		(S)
Drummer [7]	50		(S)
Bullion [7]	50	MS	(S)
Sailor [7]	45		(S)
Banquo [6]	28	MS	(S)
Aberglen [7]	20	MR	(S)

*Percent = mean of 2 replicates
All adult plant reactions susceptible unless stated
R = resistant MR = mixed resistant MS = mixed susceptible
S = susceptible (seedling reaction)
[ ] NIAB rating: 1 = susceptible; 9 = resistant

CROWN RUST OF OATS

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SEEDLING TESTS WITH 1997 ISOLATES

The origins of the three crown rust samples received in 1997 are given in Table 1. Isolates of *Puccinia coronata* were cultured from the samples and tested on the International set of 10 differential cultivars. The currently NIAB recommended winter and spring oats were also included in the tests.

Two races were identified (Table 1). Race 289, found in one isolate, carries virulence to the differential cultivars Appler and Saia, while race 251 identified in the other two isolates carries virulence to Bond in addition.

Table 1 Locations and cultivars from which crown rust samples were received in 1997 with race identified for each sample.

Isolate	Location	Cultivar	Race
CRS-97-1	Kirkcudbrightshire	Unknown	251
CRS-97-2	Cambridge	Spring Oat	251
CRS-97-3	Huntingdon	Gerald	289

Of the additional winter and spring oats included in the seedling tests, only the spring oat cvs Piper and Sailor expressed resistance, this being effective against all three isolates.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1998

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 1996 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).

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VARIETY DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST IN WHEAT, 1998

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
Cadenza
Caxton
Charger
Dynamo
Encore
Hunter
Mercia
Axona (S)
Chablis (S)
Ebony (S)
Imp (S)
Paragon (S)
Shiraz (S)

DG2
(WYR6,9)
Rialto

DG3
(WYR13)
Crofter
Riband

DG7
(WYR CV)
Consort
Hereward
Spark

DG9
(WYR17)
Abbot
Beaufort
Blaze
Brigadier
Cantata
Chaucer
Drake
Harrier
Hussar
Maverick
Reaper
Savannah

DG10
(WYR6,17)
Equinox
Madrigal

DG0
*(**)*
Soissons
Avans (S)
Baldus (S)
Fury (S)
Palermo (S)
Promessa (S)
Samoa (S)

(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, 1998

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:

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

DG1
Fighter (W)
Alexis (S)
Chalice (S)
Chariot (S)
Dandy (S)
Derkado (S)
Extract (S)
Ferment (S)
Hart (S)
Landlord (S)
Livet (S)
Riviera (S)
Tankard (S)

DG4
Tyne (S)

DG5
Baton (W)
Jewel (W)
Peridot (W)
Puffin (W)
Rifle (W)

DG7
Cooper (S)
Delibes (S)

DG8
Manitou (W)
Felicie (S)

DG9
Optic (S)

DG10
Epic (W)
Gleam (W)
Sunrise (W)

DG0
Angora (W)
Fanfare (W)
Gaelic (W)
Halcyon (W)
Hanna (W)
Intro (W)
Linnet (W)
Melanie (W)
Muscat (W)
Pastoral (W)
Pipkin (W)
Regina (W)
Spirit (W)

DG0 contd
Sprite (W)
Vertige (W)
Prisma (S)

(W) Winter barley, (S) Spring barley

Companion DG

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

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.