MILDEW OF WHEAT

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The structure of the population in 2003 was similar to 2002, with V2,4b,5, 6,8,Ta2 again the most commonly identified pathotype. Most winter varieties have no effective specific resistance although many possess good partial resistance. Exceptions are the resistant varieties Xi19 and Robigus, both thought to carry MlAx, and the newly recommended Cordiale which probably carries Mld. However, cultivars with poor specific and poor partial resistance (*e.g.* Goodwood, Bentley, Heritage, Quest) are still being introduced. The spring wheats Morph and Tybalt appear to have unknown effective specific resistance.

INTRODUCTION

Mildew levels were fairly high after the winter but then declined following either frost or rain. The dry early spring led to some increase in infection in early-sown, dense crops of susceptible varieties such as Claire and Option, although low night temperatures restricted development somewhat. Warm dry summer weather favoured infection on susceptible varieties in most areas, although the very high temperatures may have curbed development at times. Significant infection was also noted on Solstice and Bentley (both rating 4) and, particularly, on Goodwood (rating 3). In contrast, varieties such as Cordiale, Scorpion 25, Warlock 24 and Xi19 (all rating 8) had very little infection and the resistant Robigus maintained a rating of 9.

METHODS

105 samples of infected leaves were received in 2003. The samples were collected from eight locations including Cambridgeshire, Norfolk, Lincolnshire and N. Yorkshire (see Table 1).

Table 1. Source locations of leaf sample isolates in 2003.

	No. of isolates tested		No. of isolates tested
Waterbeach, Cambs.	69	Headley Hall, N. Yorks.	10
NIAB, Cambridge	34	Gleadthorpe, Notts.	9
Rothwell, Lincs.	30	Callow, Herefordshire	2
Morley, Norfolk	13	Bar Hill, Cambs.	2
TOTAL			**169**

The samples were derived from 51 cultivars, including the resistant cultivar Robigus (Table 2). 17 samples failed to produce viable conidia but single colony isolates were cultured from the remaining 88 samples.

Table 2. Source cultivars of 2003 test isolates..

	No. of isolates		No. of isolates		No. of isolates
Claire	10	Savannah	4	Senator	2
Tellus	8	Shamrock	4	Deben	2
Option	7	Soissons	4	Fenman	2
SW Tartaros	7	Gladiator	3	Malacca	2
Goodwood	6	Napier	3	Nijinsky	2
Solstice	6	Scorpion 25	3	Istabraq	2
Tanker	6	Xi19	3	Pennant	2
Steadfast	5	Access	2	Smuggler	2
Arran	4	Asosan isoline	2	Vector	2
Bentley	4	Axona (S)	2	Warlock 24	2
Consort	4	Biscay	2	Welford	2
Quest	4	Boxer	2	Wizard	2
Dickson	4	Buchan	2	Brock	1
Einstein	4	Buster	2	Crofter	1
Hereward	4	Charger	2	Dart	1
Heritage	4	Chul isoline	2	Highbury (S)	1
Richmond	4	Cordiale	2		
Robigus	4			Unknown cultivars	2
		(S) Spring cv.			
TOTAL					**169**

Seedlings of the susceptible cultivar Cerco were exposed to the air spora at five locations in Cambridgeshire, Suffolk and Lancashire in June and single colony isolates cultured from the resulting infections.

Isolates were inoculated onto detached leaf segments of differential cultivars using a spore settling tower and assessed according to the method of Moseman *et al*, 1965. The differential cultivars containing specific resistance genes/factors used to test for corresponding specific virulence genes/factors are shown in Table 3.

Einstein, Robigus, Morph, Tybalt and SW Tartaros were also included in some tests to obtain further information on the likely specific resistance genes carried by these recent cultivars.

RESULTS AND DISCUSSION

Virulence frequencies

Results of tests of isolates from both leaf and air spora samples are shown in Table 4. Differences in virulence frequency between locations are probably of little significance in view of the small sample sizes, although virulence for MlTo, MlBr and MlAx appears to be lower at Harston than at the other sites. Values for leaf and air spora samples are broadly similar.

Table 3. Differential cultivars used to determine virulence factors.

Differential cultivar	European code	Resistance genes
Cerco	none	None
Galahad	Pm2	*Pm2*
Asosan	Pm3a	*Pm3a*
Chul	Pm3b	*Pm3b*
Armada	Pm4b	*Pm4b*
Flanders	pm5	*pm5*
Brimstone	Pm2, Pm6	*Pm2, Pm6*
Clement	Pm8	*Pm8*
Amigo	Pm17	*Pm17*
Maris Dove	Mld	*Mld*
Brock	Pm2, MlTa2	*Pm2,* Unknown
Mercia	Pm5, MlTa2	*Pm5*, Unknown
Tonic	MlTo	? *Pm2* + *Pm3d*
Broom	MlBr	*Pm3d* ?
Sicco	pm5, MlSi2	*pm5,* Unknown
Wembley	MlSo	Unknown
Axona	MlAx	Unknown
Soissons	MlSs*	Unknown
Shamrock	MlSh*	Unknown

* tentative designation for specific resistance factor

Table 4. Frequency of wheat mildew virulence factors in isolates collected from leaf samples and air spora in 2003, and areas of winter cultivars with the corresponding resistance. # NIAB (2003)

	% Frequency of virulence factors						% Area of corresponding resistance #
		Random samples of airborne spores					
Virulence gene	Leaf samples	Suffolk	Ely, Cambs.	Cambridge	Harston, Cambs.	Preston, Lancs.	
2	99	100	100	100	100	100	16
3a	1	2	11	4	0	0	0
3b	7	7	0	10	17	0	0
4b	100	100	100	100	100	100	60
5	93	88	92	96	92	91	0
6	99	100	100	100	100	100	49
8	97	84	98	92	86	100	16
17	8	0	0	0	3	0	0
d	15	10	25	19	19	22	0.5
2,Ta2	98	93	100	92	92	98	0
To	18	21	25	23	11	27	0.1
Br	19	21	25	23	11	27	0
5,Si2	7	0	4	9	11	7	0
So	4	0	4	6	3	7	0
Ax	7	5	15	13	0	11	4
Ss	87	91	94	91	91	91	3
Sh	3	0	2	2	3	2	0.1
Number of isolates tested	**169**	**43**	**48**	**48**	**36**	**45**	

Table 5 gives the virulence frequencies for 1995 to 2003; there is little significant change from 2002 (Clarkson & Slater, 2003). Frequencies of virulence for Pm2, Pm4b, pm5, Pm6, Pm8 and Pm2,MlTa2 remain very high in the population, indicating a lack of effective resistance conferred by these genes. There is high selection pressure in wheat varieties for V2, V4b, V6 and V8 but none for V5 and VTa2; the latter virulences are presumably "hitchhiking" along with other virulence genes in complex pathotypes.

Virulence for MlSs, the uncharacterised specific resistance factor carried by Soissons, has now increased to 90% but the variety has reasonable partial resistance, having a rating of 7. There is a low degree of selection for virulence to Mld and MlAx and virulence frequencies remain low at present, indicating that these factors may still be conferring effective specific resistance in some varieties (see below).

V3a was detected in 2% of isolates tested, although there are no current varieties carrying Pm3a, as far as is known.

Table 5. Frequency of wheat mildew virulence factors in leaf samples collected in 1995-2003.

	Frequency of virulence factors								
Virulence factor	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003#**
2	99	100	100	100	100	100	100	99	100
3a	-	-	-	-	-	-	-	-	2
3b	4	3	4	1	2	1	4	6	7
4b	88	93	98	100	99	99	100	100	100
5	92	93	95	88	91	88	90	89	92
6	89	96	99	100	100	99	100	100	100
8	95	96	98	97	99	97	98	98	94
17	10	15	16	8	22	2	9	13	4
d	19	33	26	18	6	12	25	24	18
2,Ta2	85	92	93	86	97	96	95	99	96
To	18	29	29	16	16	5	24	20	20
Br	21	32	30	16	15	8	24	27	20
5,Si2	22	32	21	17	20	8	8	15	6
So	10	15	15	10	6	4	6	11	4
Ax	11	24	20	7	1	1	10	8	8
Ss				65	57	74	82	93	90
Sh				3	0	4	16	8	2
Number of isolates tested	**265**	**313**	**328**	**187**	**148**	**286**	**165**	**209**	**389**

includes isolates from leaf samples and airborne spores

Frequency of pathotypes

V2,4b,5,6,8,Ta2 was still the predominant pathotype present in the wheat mildew population, being found in 52% of the leaf isolates tested in 2003 (Tables 6 & 7). In air-spora isolate tests, this pathotype was slightly less common at Harston than at the other sites (Table 6), although sample numbers were fairly low in these tests. More pathotypes were detected in the

leaf samples: these isolates originate mostly from variety trials where there is greater variation in selection pressure.

Table 6. Frequencies of the most commonly identified pathotypes in leaf isolates and air spora in 2003, as defined by the factors in Table 3, with the exception of Pm3a (Asosan), MlSs (Soissons) and MlSh (Shamrock).

	Frequency of pathotypes (%)					
Pathotype	**Leaf isolates**	**Suffolk**	**Ely, Cambs**	**Cambridge**	**Harston, Cambs**	**Preston, Lancs**
2,4b,5,6,8	2	2	0	2	3	0
2,4b,6,8,Ta2	7	7	8	2	6	4
2,4b,5,8,Ta2	0	0	0	0	0	0
2,4b,5,6,8,Ta2	52	44	50	48	31	51
2,4b,5,6,8,Ta2,To,Br	13	9	6	10	8	20
2,4b,5,6,8,Ta2,Si2	0	0	0	0	0	0
2,4b,5,6,8,Ta2,Si2,So	0	0	2	0	3	2
2,4b,5,6,8,d,Ta2	8	2	6	2	11	4
2,4b,5,6,8,d,Ta2,To,Br,Ax	9	2	15	6	0	7
2,3b,4,5,6,8,Ta2	9	0	0	6	8	0
Number of pathotypes	**35**	**16**	**18**	**20**	**22**	**15**
Number of isolates tested	**169**	**43**	**48**	**48**	**36**	**45**
Ratio no. pathotypes/no. isols	**0.21**	**0.37**	**0.38**	**0.42**	**0.61**	**0.33**

Table 7 shows the pathotype frequencies for 1994 to 2003. There has been little change in the population composition in recent years.

Table 7. Frequencies of the most commonly identified pathotypes in isolates, 1994-2003, as defined by the factors in Table 3, with the exception of Pm3a (Asosan), MlSs (Soissons) and MlSh (Shamrock).

	Frequency of pathotypes (%)									
Pathotype	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
2,4b,5,6,8	8	8	4	3	9	<1	2	1	0	2
2,4b,6,8,Ta2	2	3	1	2	6	5	8	5	2	7
2,4b,5,8,Ta2	4	2	1	<1	0	0	1	0	0	0
2,4b,5,6,8,Ta2	26	38	35	42	38	57	61	41	36	52
2,4b,5,6,8,Ta2,To,Br	5	6	4	7	5	9	1	10	8	13
2,4b,5,6,8,Ta2,Si2	2	4	6	4	5	11	2	1	1	0
2,4b,5,6,8,Ta2,Si2,So	6	8	4	7	4	2	2	3	2	0
2,4b,5,6,8,d,Ta2	7	5	5	3	6	2	7	12	10	8
2,4b,5,6,8,d,Ta2,To,Br,Ax	3	3	6	10	1	<1	1	5	1	9
2,3b,4,5,6,8,Ta2	-	0	1	1	0	0	<1	2	<1	9
Number of pathotypes	**71**	**57**	**59**	**44**	**35**	**22**	**37**	**44**	**49**	**35**
Number of isolates tested	**347**	**265**	**313**	**328**	**187**	**148**	**286**	**165**	**209**	**169**
Ratio no. pathotypes/no. isols	**0.20**	**0.22**	**0.19**	**0.13**	**0.19**	**0.15**	**0.13**	**0.27**	**0.23**	**0.21**

Complexity of isolates

Table 8 shows the number of virulence factors carried by pathotypes detected in both leaf and air-spora samples in 2003. Data do not indicate major differences between sources of isolates. Most isolates carry at least 6 virulence factors, as in recent years (Table 9).

Table 8. Frequencies of the most commonly identified pathotypes in leaf samples and isolates from air spora in Cambridgeshire, Suffolk and Lancashire in 2003.

Virulence factor	Frequency of isolates with varying numbers of virulence factors(%)					
	Leaf isolates	Suffolk	Ely, Cambs	Cherry Hinton, Cambridge	Harston, Cambs	Preston, Lancs
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	<1	0	0	0	0	0
4	<1	2	0	6	6	2
5	7	26	10	8	14	4
6	60	49	54	56	50	58
7	11	5	8	2	17	7
8	11	14	8	10	14	18
9	2	0	4	4	0	2
10	7	5	15	5	0	4
11	0	0	0	0	0	0
12	0	0	0	2	0	4
Number of isolates tested	**169**	**43**	**48**	**48**	**36**	**45**

Table 9. Number of virulence factors in the wheat mildew population, 1997-2003.

Number of virulence factors*	Frequency of isolates with each number of virulences (%)						
	1997	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**
0	0	0	0	<1	0	0	0
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	<1	1	0	0	<1
4	1	2	0	1	2	<1	2
5	7	18	7	13	8	11	10
6	45	44	59	63	47	44	57
7	9	15	16	13	15	18	9
8	16	11	13	5	15	12	12
9	4	4	2	2	4	6	2
10	13	5	3	2	7	7	7
11	2	0	0	0	0	1	0
12	3	2	0	<1	1	<1	1

* corresponding to the resistance genes/factors in Table 3, with the exception of Pm3a (Asosan), Pm3b (Chul), Pm17 (Amigo), MlSs (Soissons) and MlSh (Shamrock).

Almost all the isolates tested infected the additional test cultivars Einstein and SW Tartaros (Table 10). The spring cultivar Morph was susceptible to 2% of leaf isolates and 6% of airborne spores, while Tybalt was resistant to all isolates tested. Although Robigus (winter) was resistant to isolates collected from Robigus, 1% (3 isolates) of isolates taken from airborne spores infected Robigus in differential tests. These Robigus-virulent isolates all carry virulence for Axona, indicating that Robigus may carry MlAx.

Table 10. Infection levels on additional cultivars included in differential tests in 2003

Cultivar	Percentage number of virulent isolates	
	Leaf samples	Air spora
Einstein	93	94
SW Tartaros	95	99
Robigus	0	1
Morph	2	6
Tybalt	0	0

Infection of winter and spring wheat cultivars

35 of the 40 winter cultivars in RL trials in 2003 are potentially susceptible to the most frequently identified pathotype, V2,V4b,V5,V6,V8,VTa2. Only five cultivars (Xi19, Scorpion 25, Warlock 24, Robigus and Cordiale) carry specific resistance effective in the field. However, many cultivars (*e.g.* Charger, Malacca) carry effective non-specific resistance (Table 11). It is of concern that there appears to be a lack of effective non-specific resistance in the RL cultivars Claire, Option and Solstice (all rating 4) and the 2003 RL candidate cultivars Goodwood (3), Bentley, Heritage and Quest (all 4).

RESISTANCE FACTORS OF NEW CULTIVARS

The specific resistance genes/factors found to be carried by current winter and spring wheat cultivars in 2003 tests are shown in Table 12. Xi19 (rating 8) and the spring variety Ashby (rating (7)) carry effective specific resistance conferred by MlAx. Robigus retains a rating of 9, although a few virulent isolates have been detected; this variety is thought to carry MlAx and probably additional resistance. Of the newly recommended winter cultivars, Cordiale appears to have moderately good resistance, probably conferred by Mld, while Dickson, Nijinsky, Istabraq, Gladiator, Smuggler and Welford have no effective specific resistance genes but have varying levels of partial resistance. No new spring cultivars have been recommended for 2004.

Table 11. Proportion of mildew isolates able to infect wheat cultivars in HGCA Recommended List trials in 2003. (2004 Recommended List cultivars in **bold**; mildew resistance ratings in brackets.)

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Winter			
Claire (4)	100	Quest (4)	100
Consort (6)	100	Vector (5)	100
Charger (8)	100	SW Tartaros (5)	97
Malacca (7)	100	**Access** (7)	94
Option (4)	100	**Equinox** (5)	94
Hereward (5)	100	**Tanker** (6)	94
Solstice (4)	100	Buchan (7)	94
Riband (6)	100	**Napier** (7)	94
Deben (6)	100	**Savannah** (7)	94
Biscay (5)	100	**Einstein** (7)	94
Richmond (5)	100	**Gladiato**r (7)	94
Tellus (5)	100	Steadfast (6)	94
Goodwood (3)	100	Senator (6)	94
Arran (5)	100	**Welford** (6)	94
Wizard (7)	100	Pennant (7)	94
Smuggler (7)	100	**Soissons** (7)	90
Bentley (4)	100	**Cordiale** (7)	18?
Nijinsky (6)	100	**Xi19** (8)	8
Dickson (5)	100	Scorpion 25 (8)	8
Dart (5)	100	Warlock 24 (8)	8
Istabraq (5)	100	**Robigus** (9)	1
Heritage (4)	100		
Spring			
Paragon (7)	100	**Ashby** ((7))	8
Wallace ((7))	100	Jester ((5))	8?
Ambient ((6))	100?	**Morph** ((8))	4
Chablis (4)	20	**Tybalt** ((9))	0
Belvoir ((6))	20?	Byron ((6))	?

Table 12. Specific mildew resistance genes/factors in wheat cultivars (2004 Recommended List cultivars in **bold**).

None	*Pm2,4b,6*	*Pm2,Pm4b,Pm8* (*Pm6*?)
Charger	Arran	**Access**
Hereward	Biscay	
Goodwood	**Consort**	*Mld*?
Solstice	Quest	**Cordiale**
Vector	Dart	
Imp (S)	**Deben**	*MlAx*
Paragon (S)	**Dickson**	Scorpion 25
	Malacca	Warlock 24
Pm2	**Nijinsky**	**Xi19**
Heritage	**Riband**	**Ashby (S)**
Tellus	**Richmond**	Jester (S)
Ambient (S)	**Wizard**	
Wallace (S)		*MlBr*
	Pm8	**Chablis (S)**
Pm2+?	Steadfast	
Einstein	**Welford**	*Pm2,MlBr*
		Belvoir (S)
Pm2,Pm4b	*Pm4b,Pm8*	
Claire	Senator	Rx ?
Bentley	Pennant	**Morph (S)**
Istabraq		**Tybalt** (S)
	Pm4b,Pm6,Pm8?	Byron (S)
Pm2,6	**Tanker**	
Option		*MlAx* +?
Smuggler	*Pm2,Pm4b,Pm6,Pm8*	**Robigus**
	Equinox	
	Gladiator	MlSs
	Napier	**Soissons**
	Savannah	
		?
(S) Spring wheat		SW Tartaros

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MILDEW OF BARLEY

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Fluctuating disease levels during spring and summer 2003 resulted in the receipt of only 136 samples of infected leaves. Further samples were collected from airborne spores in East Anglia and Lancashire. Vh, Vra, Vg, V(CP), VLa, Va12, Va7 and V(Ab) were present at similar high levels in isolates from both infected leaves and airborne spores. Va3 was detected in 5% of isolates tested. The majority of isolates tested carried nine virulence factors, corresponding to pathotype Vh,Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1, detected in 49% of isolates. All currently grown winter cultivars except Sequel, Vanessa and Leonie are susceptible to this pathotype, as is Optic, the most popular spring cultivar. The population continued the trend towards reduced heterogeneity, with fewer pathotypes detected. The majority of winter cultivars are potentially susceptible to over 90% of the mildew population. However, many cultivars have good non-specific resistance. All spring cultivars except Optic (rating 5) carry good resistance with ratings of 7 and above. Although the resistance of some of the new cultivars is unknown, the majority of spring barleys carry *mlo*, which remains effective in the field. However, isolates partially virulent on *mlo* differentials were again detected.

INTRODUCTION

The high post-winter disease levels declined during February but there was a subsequent increase in eastern and western areas during the dry settled March weather, particularly on the susceptible cultivar Regina. Further development took place in the dry summer, particularly in north-eastern and eastern England but levels were rather variable across the country by the end of the season, with no particular pattern apparent. The susceptible varieties Cannock, Pastoral (both rating 2) and Heligan (rating 3) carried substantial infection in some areas in 2003. Conversely, a number of winter barley varieties with ratings of 8 showed good resistance, including the newer varieties Sequel and Tallica.

Most new and existing spring barley varieties have excellent resistance to mildew, conferred by the *mlo* gene, and infection on such varieties is very rare. The most susceptible variety is Optic which showed fairly high infection levels in 2003, particularly on the eastern side of England. The newcomer Beryllium (rating 7) also appears fairly susceptible and exhibited similar infection levels to Optic.

METHODS

Virulence survey

136 samples of infected leaves were received in 2003, the second lowest number since 1998 (Slater & Clarkson, 2003). 27 samples failed to produce viable conidia but 207 single colony isolates were cultured from the remaining 109 samples and tested. The locations from which the tested isolates were collected are shown in Table 1.

Table 1. Locations from which tested isolates were collected in 2003.

Location	Number of isolates	Location	Number of isolates
NIAB, Cambridge	94	St. Boswells, Borders	12
Rothwell, Lincs.	40	Auchincruive, Ayr	10
Cockle Park, Northumb.	20	Gleadthorpe, Notts.	10
Headley Hall, Yorks.	18	Callow, Herefords.	3
Total number of isolates tested			207

The isolates were collected from 37 winter cultivars and 14 spring cultivars, including five *mlo*-carrying cultivars (Table 2). Seedlings of the susceptible cultivar Golden Promise were exposed to the air spora at five locations in Cambridgeshire, Suffolk and Lancashire and single colony isolates cultured from the resulting infection.

Table 2. Cultivars from which tested isolates were collected in 2003.

Spring cultivars

	isolates		isolates		isolates
Riviera	14	Cellar	5	Chalice	2
Optic	8	Prestige	4	Cocktail	2
Doyen	7	Rebecca	4	Spire	2
Kirsty	6	Beryllium	2	Toby	2
Feltwell	6	Carafe	2	Decanter	1

Winter cultivars

	isolates		isolates		isolates
Regina	11	Jewel	4	Camion	2
Clara	8	Pedigree	4	Carousel	2
Antelope	6	Scylla	4	Eden	2
Carat	6	Siberia	4	Fighter	2
Kestrel	6	Swallow	4	Flute	2
Leonie	6	Vanessa	4	Heligan	2
Pearl	6	Wigwam	4	Jackpot	2
Sumo	6	Colossus	3	Ludine	2
Cannock	5	Diamond	3	Sonja	2
Nocturne	5	Kielder	3	Angela	1
Pastoral	5	Angora	2	Connoisseur	1
Antonia	4	Artist	2	Pict	1
Aquarelle	4				

The cultivars used to determine virulence factors present in isolates, together with their resistance factors, are shown in Table 3.

Table 3. Differential cultivars used to determine virulence factors in isolates of barley mildew.

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

The winter barley cultivars Vanessa, Leonie and Clara and the spring cultivars Kirsty, Carafe, Toby, Rebecca, Feltwell and Novello were also included in some tests.

RESULTS AND DISCUSSION

Virulence

Table 4 shows the virulence frequencies in the six sets of isolates tested in 2003. The commonly occurring virulence factors, *Vh*, *Vra*, *Vg*, *V(CP)*, *VLa*, *Va12*, *Va7* and *V(Ab)*, were detected at similar levels in the leaf samples and the airborne spora. The differences observed, e.g. less frequent occurrence of *V(CP)* and *Va12* in the Suffolk sample, are probably due to the small sample size (only 14 isolates from Suffolk). *Va9* and *Va3* were less frequently identified in samples from Ely, Cambridge and Harston, while *Va13* occurred more frequently in the leaf samples. The samples collected in Lancashire did not appear particularly different from those collected in East Anglia.

Table 4. Virulence frequencies in single colony isolates of barley mildew from infected leaves (leaf sample) and from random samples of airborne spores, and the area of barley cultivars with the corresponding resistance factors in 2003.

	% Frequency of virulence factors							% Area of corresponding
	Leaf samples		Random samples of airborne spores					resistance #
Virulence gene	All leaf data	Non-corresponding virulence *	Suffolk	Ely, Cambs.	Cambridge	Harston, Cambs.	Preston, Lancs.	
Vh	91	89	93	94	82	93	97	30
Vra	100	100	100	100	100	100	100	38
Vg	100	99	100	100	100	98	100	30
V(CP)	99	99	93	100	100	98	100	30
Va6	11	10	7	13	4	8	5	2
VLa	97	96	100	91	100	100	100	<1
Va12	97	97	93	96	100	100	98	33
Vk1	41	41	43	27	29	30	28	0
Va7	98	98	93	94	93	88	100	2
V(Ab)	91	91	93	100	100	100	98	24
Va1	74	74	71	90	78	83	91	1
Va9	15	15	14	0	2	5	16	<1
vo	0	0	0	0	0	0	0	23
Va13	16	14	0	0	2	0	5	4
Va3	7	7	7	0	0	0	5	0
No. of isols.	**207**		**14**	**48**	**45**	**40**	**57**	

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

\# NIAB (2003)

Virulence frequencies calculated from all leaf isolates and from isolates collected from cultivars with non-corresponding resistance genes were almost identical. This indicates that isolates carrying specific virulence factors are not restricted to cultivars carrying corresponding resistance factors. The ability of the barley mildew population to infect a range of cultivars reduces the potential for diversification and aids the build-up and spread of new pathotypes.

The frequencies of *Vra*, *Vg*, *V(CP)*, *Va12*, *Va7* and *V(Ab)*, shown in Table 5, remained high, at or near 100%. With the exception of *Va7* and *V(Ab)* this reflects significant selection by around a third of the barley grown in 2003. Cultivars carrying *Ml(Ab)*, all spring sown, account for almost a quarter of the total barley area but despite the decline of *Mla7*-carrying cultivars (e.g. Regina) in recent years the corresponding virulence remains common. *VLa* was also detected in over 90% of the isolates tested despite only limited selection for several years.

The increase in frequency of Vh continued in 2003, now at its highest for many years. There has been an increase in the occurrence of Va1 through the years covered by Table 5 despite a reduction in area grown of cultivars carrying Mla1 over this time. There has also been a decline in area sown to cultivars carrying Mla6, Mla9 and Mla13 but this has resulted in a reduction in the frequency of the corresponding virulence in the population. Vk1, for which there has been no selection since the 1980s, continued to decrease.

Table 5. Virulence frequencies in barley mildew, 1993 to 2003.

Virulence gene	Virulence frequency (%) *										
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
Vh	78	79	70	78	68	61	58	50	68	83	92
Vra	100	99	100	100	100	100	100	100	100	100	100
Vg	96	95	95	96	95	97	97	97	99	99	100
V(CP)	92	88	90	90	93	94	95	96	98	97	99
Va6	35	31	34	30	25	31	26	23	19	20	9
VLa	22	25	31	56	58	72	89	88	95	92	97
Va12	72	67	71	70	73	76	87	88	99	99	98
Vk1	75	72	72	76	71	73	66	61	57	52	35
Va7	76	69	73	76	73	76	85	95	99	96	96
V(Ab)	76	74	67	62	52	53	71	79	95	95	95
Va1	18	23	27	38	36	45	64	65	67	73	80
Va9	29	34	33	37	33	32	25	29	28	15	11
Va13	38	43	37	41	39	25	19	11	17	13	9
Va3	1	<1	<1	<1	1	1	1	5	1	2	5
No. of isolates	628	539	552	428	551	743	629	689	235	339	413

* Mean of leaf samples and random samples of airborne spores for each year. Data from Slater & Clarkson (2003).

Va3 has fluctuated over the years, but has shown a small trend towards increased frequency in the last few years. It is possible that Toby, a candidate cultivar for recommendation in 2003, carries Mla3.

Complexity of isolates

Table 6 shows the number of virulence factors carried by isolates tested in 2003.

Table 6. Complexity of isolates taken from leaf samples and airborne spores in 2003

Virulence genes*	Relative number of isolates					
	Leaf samples	Random samples of airborne spores				
		Suffolk	Ely, Cambs.	Cambridge	Harston, Cambs.	Preston, Lancs.
0	0	0	0	0	0	0
1	0	0	0	0	0	0
2	0	0	0	0	0	0
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	<1	0	0	0	0	0
6	1	7	0	2	3	0
7	2	0	4	2	0	0
8	10	14	11	13	8	4
9	46	50	69	69	78	60
10	27	14	13	11	10	26
11	10	14	4	2	3	11
12	7	0	0	0	0	0
13	0	0	0	0	0	0
No. of isols.	**207**	**14**	**45**	**45**	**40**	**57**

* includes all virulences listed in Table 2

The trend towards more complex isolates continued with over half the isolates tested in 2003 carrying nine virulence factors, compared to 30% in 2002 (see Table 7). Only a few isolates

carried 12 factors and none carried 13 factors, the maximum number so far detected. The Lancashire population, however, tended to consist of slightly more complex isolates, the simplest pathotype carrying eight virulence factors. Simple isolates, with fewer than five factors, were not detected in 2003.

Table 7. Comparison of the complexity of isolates collected from 1993 to 2003.

Number of virulence factors	% Frequency of isolates with each number of virulences*										
	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003
0	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0	0	0
2	<1	0	<1	<1	0	0	0	0	0	0	0
3	<1	0	<1	1	0	<1	0	0	0	0	0
4	4	1	1	1	1	1	1	1	0	0	0
5	18	4	4	3	4	4	1	1	<1	<1	<1
6	34	10	11	7	11	10	8	6	0	1	1
7	27	24	19	14	17	15	10	8	5	4	2
8	10	25	28	22	23	22	21	21	17	17	9
9	4	16	20	24	21	18	18	26	29	30	57
10	1	12	10	16	16	20	25	24	29	31	21
11	<1	4	5	10	4	6	12	11	14	12	8
12	0	2	1	8	2	2	3	1	4	2	2
13	0	0	0	3	<1	<1	1	0	0	2	0
Total no. of isolates	628	539	552	428	551	743	629	689	235	339	413

* includes all virulences listed in Table 2

The commonest pathotype detected in 2003, identified in 49% of isolates tested, was again *Vh,Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1*. This pathotype carries nine virulence factors, which correspond to the resistance genes carried by the most popular barley cultivars. Of the currently grown winter cultivars, only Sequel (*Mla6*), Vanessa and Leonie are resistant to this pathotype. Amongst spring barleys, the most popular cultivar Optic (*Mla12,Ml(Ab)*) is susceptible to the common pathotype. Thus, at present there appears to be little selection for further combinations of virulence factors and the population components may stabilise at the current level of complexity.

Table 8. Number of pathotypes identified, 1995-2003.

	Total number of isolates tested	Number of pathotypes	Ratio of number of pathotypes to number of isolates tested	% frequency of commonest pathotype
1995	552	298	0.54	3
1996	428	238	0.56	3
1997	551	277	0.50	4
1998	743	302	0.41	6
1999	629	202	0.32	8
2000	689	190	0.28	10
2001	235	61	0.26	10
2002	339	73	0.22	22
2003	413	71	0.17	49

The data in Table 8 illustrate the trend towards reduced heterogeneity in the mildew population. Fewer pathotypes were again detected in 2003: only 71 from 413 isolates tested. The ratio of pathotypes to number of isolates tested has decreased steadily since 1995,

alongside the increase in the commonest pathotype. The population is now dominated by a single complex pathotype capable of infecting the bulk of the barley grown.

Infection of barley cultivars

Table 9. Proportion of mildew isolates tested in 2003 able to infect barley cultivars in HGCA Recommended List trials (Rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Antelope (7)	100	Colossus (5)	92
Cannock (2)	100	Camion (5)	92
Eden (4)	100	Haka (8)	92
Pastoral (2)	100	Kestrel (4)	92
Pict (7)	100	Pearl (7)	92
Swallow (7)	99	Scylla (6)	92
Carat (7)	98	Siberia (7)	92
Diamond (7)	98	Wigwam (7)	92
Pedigree (6)	98	Vanessa (8)	14
Jewel (6)	98	Leonie (8)	14
Aquarelle (6)	96	Clara (7)	14
Nocturne (4)	96	Tallica (8)	9
Regina (3)	96	Kielder (6)	9
Angela (8)	92	Sequel (8)	9
Connoisseur (7)	92	Sumo (7)	?

Spring cultivars	Proportion (%)	Spring cultivars	Proportion (%)
Optic (5)	95	Chalice (9)	0
Beryllium (7)	95	Drum (9)	0
Kirsty (8)	13	Decanter (9)	0
Rebecca (8)	12	Doyen (9)	0
Spire (8)	9	Prestige (9)	0
Feltwell (8)	9	Riviera (9)	0
Toby (9)	1	Static (9)	0
Carafe (9)	1	Troon (9)	0
Athena (9)	0	Cocktail (8)	?
Cellar (9)	0		

The majority of winter cultivars are susceptible to over 90% of population, only Vanessa, Leonie, Clara, Tallica, Kielder and Sequel showing good specific resistance (see Table 9). However, many cultivars possess good non-specific resistance e.g. Angela (rating 8, susceptible to 92% of population) and Carat (rating 7, susceptible to 98%). New spring cultivars in RL trials in 2003 showed good resistance to mildew. Only Optic and Beryllium are potentially susceptible to a substantial part of the population, but both carry some non-specific resistance. 10 of the spring cultivars shown in Table 9 probably carry *mlo,* which remains effective in the field. The frequency of virulence corresponding to the uncharacterised resistance factors in Sumo (winter) and Cocktail (spring) is unknown.

Resistance factors in new cultivars

Additional cultivars carrying good, unknown resistance were included in differential tests. The number of isolates virulent on these cultivars in tests is shown in Table 10. All isolates virulent on Clara also infected Vanessa and Leonie, and vice versa, suggesting these three cultivars carry resistance in common. Of the isolates virulent on the spring cultivar Kirsty, the majority also infected Vanessa, Leonie and Clara. Some of the isolates virulent on Vanessa were also virulent on Rebecca. All the isolates virulent on Feltwell also carried *Va13*, indicating that Feltwell carries *Mla13*. Virulence for Carafe has been confirmed in three isolates. Virulence for Toby has been confirmed in six isolates, although five further isolates may also carry virulence. All 11 of these isolates carried virulence *Va3,* suggesting that Toby carries *Mla3*.

Table 10. Relative number of isolates virulent on additional cultivars included in differential tests in 2003

	Relative number of isolates					
	Leaf samples	Random samples of airborne spores				
		Suffolk	Ely, Cambs.	Cambridge	Harston, Cambs.	Preston, Lancs.
Vanessa (w)	24	1	4	2	3	7
Leonie (w)	24	1	4	2	3	7
Clara (w)	24	1	4	2	3	7
Kirsty (s)	20	1	4	2	3	7
Rebecca (s)	2	0	0	4	0	7
Feltwell (s)	15	0	0	2	0	3
Carafe (s)	1	0	0	0	0	2
Toby (s)	2	1	0	0	0	4
No. of isols.	**207**	**14**	**48**	**45**	**40**	**57**

The resistance genes detected in cultivars in Recommended List trials in 2003 are shown in Table 11. Carafe, Kirsty, Doyen, Rebecca (all spring) and the winter cultivar Sumo carry unknown specific resistance. Clara appears to carry resistance similar to Vanessa and Leonie. Toby may carry Mla3, the first commercial cultivar in the UK to do so.

Table 11. Resistance genes of barley cultivars (2004 HGCA Recommended List cultivars in **bold**).

Mlra	*Mlh,Mlra(Mla6,Mlv?)*	*Mla13*
Eden (W)	Kielder **(**W)	Feltwell (S)
Heligan (W)		**Spire** (S)
Muscat (W)	*Mlra,Mla6*	
Pict (W)	**Sequel** (W)	*Mla13 ?*
Pastoral (W)		**Cocktail** (S)
	Mla12	
Mlra?	**Jewel** (W)	*mlo*
Antelope (W)	Pedigree (W)	Athena (S)
Cannock (W)		**Cellar** (S)
	Mlra,Mla12	**Chalice** (S)
Mlh,Mlra	Diamond (W)	**Decanter** (S)
Angela (W)		Drum (S)
Colossus (W)*	*Mlra,Mlg,Mla12*	**Prestige** (S)
Connoisseur (W)	**Carat** (W)	**Riviera** (S)
Haka (W)		**Static** (S)
Siberia (W)	*Mlh,Mlra,Mlg,Mla12*	**Troon** (S)
	Wigwam (W)	
Mlh, Mlg		*Mla3?*
Antonia (W)	*Mla7 (Mlra?)*	Toby (S)
	Aquarelle (W)*	
Mlra,Mlg,Ml(CP)	Nocturne (W)	'Van'
Fanfare (W)	**Regina** (W)	Clara (W)
Swallow (W)		Leonie (W)
	Mlh,Mlra,Mla7	**Vanessa** (W)
Mlh,Mlra,Mlg,Ml(CP)	Vertige (W)	
Camion (W)*		Unknown
Kestrel (W)	*Mla12,Ml(Ab)*	**Carafe** (S)*
Pearl (W)	Beryllium (S)	**Doyen** (S)*
Scylla (W)	**Optic** (S)	**Kirsty** (S)
		Rebecca (S)*
Mlh,Mla6		**Sumo** (W)
Tallica (W)		
* newly recommended for 2004	(W) winter cultivar	(S) spring cultivar

Virulence for *mlo* cultivars

Following the decrease observed in 2002, the number of isolates showing limited infection on Apex and Riviera in tests rose in 2003 (Table 12). Infection on these *mlo* differentials varied between the sets of samples analysed in 2003, e.g. 63% of isolates from Harston gave some infection on Apex, but only 33% of Cambridge isolates. This difference was probably due to differences in local populations, the source of spores and environmental factors affecting testing conditions. Each set of isolates from airborne spores was relatively small (e.g. Harston = 40 isolates, Cambridge = 45), so differences are less likely to be significant. The total airborne spore isolates gave 42% of Apex-infective isolates (from total of 204 isolates) compared to 43% of leaf samples (from total of 207 isolates).

Table 12. Proportion of isolates infecting Apex and Riviera in differential tests, 1996-2003 (as percentage of isolates tested)

Year	Apex	Riviera
1996	29	15
1997	24	13
1998	29	24
1999	27	23
2000	44	32
2001	48	34
2002	30	13
2003	43	27

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MILDEW OF OATS

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INTRODUCTION

13 samples were received from 3 winter and 4 spring oat cvs (Table1). They were from trial sites in Fife (7 samples), Ceredigion (3 samples) and Co. Down (3 samples).

Table 1 Source cultivars of 2003 oat mildew samples

Cv. [1-9 rating]	No. of samples	Cv. [1-9 rating]	No. of samples
Winter oat		Spring oat	
Buffalo[2]	2	Drummer[6]	3
Millennium[4]	2	Winston[8]	2
Jalna[6]	1	Firth[5]	2
		Banquo[8]	1

SEEDLING TESTS WITH 2003 ISOLATES

Methods

Isolates of *Blumeria graminis* DC Speer f.sp. *avenae* were cultured from 5 samples. They were inoculated onto seedlings of the differential cvs (Table 2) and cvs on the HGCA Recommended Lists of winter and spring oats. Post-inoculation plants were incubated in the glasshouse at approximately 15^{o}C for 14 days. Isolate/cv. interactions were classified on the standard 0-4 scale as resistant (0-2) or susceptible (3-4).

Table 2 Differential cultivars used for isolate testing

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

Results

Based on the reactions of the differential cvs, all isolates were identified as carrying the widely virulent race 5 (OMV-1,2,3) which has been at a high frequency in the population for several years. Virulence to the *A. barbata* resistance in the translocation line Cc6490 (OMR-4) was not detected. This resistance has not been carried by any recommended cv. but may be in some advanced breeding lines. The corresponding virulence has been identified but has remained at a low frequency over several years.

Although all the currently recommended winter and spring oat cvs were susceptible, there does appear to be good levels of adult plant resistance particulary in spring oats as indicated by the disease ratings in Table1.

YELLOW RUST OF WHEAT

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SUMMARY

Virulence for Oxbow was identified in 50% of the isolates tested in 2003. All of these carried the virulence combination WYV9,17,CV.
The new combination WYV6,9,17,CV, identified provisionally in 2002, was detected in a small number of 2003 isolates, which are undergoing further tests.
There was evidence that the resistant cultivars Solstice and Parade may be affected by new pathotypes of yellow rust. There were also indications of virulence for the differential cultivar Spaldings Prolific.
Many new and established cultivars retained their resistance to the most recent yellow rust isolates.

INTRODUCTION

The incidence of yellow rust was low in 2003, due to a combination of dry weather conditions during late spring and summer and a relatively small area of highly susceptible varieties (Table 1).

SEEDLING VIRULENCE TESTS OF ISOLATES COLLECTED IN 2003

Methods

28 samples of wheat yellow rust were received from naturally infected plots and crops between April and June from which 14 isolates were successfully cultured and tested. An additional 16 isolates, made from samples collected from inoculated plots at Cambridge, were also tested.

Virulence tests were carried out on seedlings of the differential cultivars listed in Table 3, using the methods described by Priestley, Bayles and Thomas, 1984. Several additional cultivars, of particular relevance to UK breeding, were also included. Some of these possess resistance that continues to be effective against all known UK pathotypes.

Table 1. UK winter wheat cultivars for 2003, yellow rust resistance ratings (1-9), area grown, number of samples received / isolates tested from naturally infections.

Cultivar	WYR factors	1-9 resistance rating*	% Area grown#	No. of samples received	No. of isolates tested
Claire	x, APR	9	14.8	1	0
Consort	CV+	5	12.6	2	1
Malacca	x, APR	9	7.4	0	0
Solstice	R	9	7.4	0	0
Tanker	9	5	5.4	2	0
Hereward	CV+	5	4.9	0	0
Access	6,9,17	3	4.3	1	1
Einstein	?6+	6	4.2	0	0
Deben	x, APR	9	4.1	1	0
Robigus	CV+	3	4.0	5	2
Option	R	9	3.9	0	0
Xi 19	R?	9	3.9	1	0
Napier	6,9,17	3	3.5	1	0
Soissons	3	7	3.0	1	1
Goodwood	?6+	7	2.4	1	0
Wizard	CV+	4	1.8	1	1
Savannah	9,17	5	1.7	1	0
Richmond	R	8	1.6	0	0
Charger	x, APR	8	0.7	0	0
Biscay	9,17	4	0.2	1	1
Scorpion 25	R?	9	0.0	0	0
Buchan	9,17	3	-	2	1
Other cvs		-	-	7	6
TOTAL				**28**	**14**

*HGCA Recommended List resistance ratings for 2003, or most recent where cultivar is no longer recommended (HGCA, 2003)

Cultivars recommended for 2003 in **bold**

NIAB seed production statistics for England and Wales for 2003

Table 2. Locations from which yellow rust samples were received in 2003 (natural infections).

Region	County	No of samples received	No of isolates tested
East Anglia	Cambridgeshire	23	12
East Midlands	Lincolnshire	4	2
North East	Durham	1	0
TOTAL		**28**	**14**

Table 3. Differential cultivars used in 2003 wheat seedling virulence tests.

Differential cultivar	WYR factor	Gene designation
Core set		
Chinese 166	WYR1	*Yr1*
Kalysona	WYR2	*Yr2*
Vilmorin 23	WYR3	*Yr3*+
Nord Desprez	WYR3	*Yr3*+
Hybrid 46	WYR4	*Yr4*
Heines Kolben	WYR2,6	*Yr2, Yr6*
Heines Peko	WYR2,6	*Yr2, Yr6*
Lee	WYR7	*Yr7*
Reichersberg 42	WYR7	*Yr7*
Compair	WYR8	*Yr8*
Kavkaz x 4 Fed	WYR9	*Yr9*
Clement	WYR9	*Yr9*
Moro	WYR10	*Yr10*
Yr 15/6*AvS	WYR15	*Yr15*
VPM 1	WYR17	*Yr17*
Rendezvous	WYR17	*Yr17*
Carstens V	WYRCV	*Yr32*
Suwon x Omar	WYRSo	*Yr Suwon x Omar*
Strubes Dickopf	WYRSd	*Yr Strubes Dickopf*
Spaldings Prolific	WYRSp	*Yr Spaldings Prolific*
Additional CVs		
Oxbow	CV+	
Cadenza	R	
Option	R	
Solstice	R	
Xi19	R	
Buster	R	

Results

Isolates from natural infections

Results of the 2003 virulence tests, together with data from 1989 – 2002 (Bayles *et al,* 2002), are shown in Table 4. Virulence frequencies should be interpreted with caution due to the non-random nature of the sampling and the small number of isolates tested in some years.

WYV1, WYV2, WYV3 and WYVSo were detected in all isolates. Other virulences detected at very high frequencies were WYV4, WYV9, WYV17, WYVCV, and WYVSd. There was a noticeable increase in the frequency of WYV7, which rose to 36%.

For the first time there were indications of virulence for the differential Spaldings Prolific (WYRSp) and for the additional cultivar Parade. The isolates concerned are undergoing confirmatory tests.

No virulence was detected for WYR8, WYR10, WYR15, Cadenza, Option or Xi19 in isolates from naturally infected sources.

Table 4. Frequency of virulence from 1989 to 2003 (natural infections)

Virulence for:		**89**	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**
WYR1		62	85	91	88	89	65	90	97	100	99	99	100	100	97	100
WYR2		100	100	100	100	98	100	99	97	100	99	99	100	100	97	100
WYR3		100	100	100	100	100	100	100	100	100	100	100	100	100	97	100
WYR4		97	91	86	86	89	86	67	59	47	79	87	90	74	63	86
WYR6		57	69	64	88	68	41	35	16	1	7	21	32	39	31	50
WYR7		2	9	19	7	8	4	0	3	7	4	10	4	0	3	36
WYR8				0	0	0	0	0	0	0	0	0	0	0	0	0
WYR9		99	94	88	76	84	94	95	97	99	99	99	92	90	88	93
WYR10														0	0	0
WYR15														0	0	0
WYR17								57	84	99	99	100	96	77	88	93
WYRCV							75	55	9	13	1	4	16	42	73	64
WYRA											84	91	88	90	97	-
WYRSo											78	91	90	77	67	93
WYRSd											100	98	100	84	81	100
WYRSp											0	0	0	0	0	7
Additional cvs																
Oxbow	9,CV+												16	32	50	50
Parade*	R					3	0	0	0	0	0	0	0	0	0	7
Cadenza	R													0	0	0
Option	R														0	0
Solstice	R?														6	7
Xi19	R														0	0
No. of isolates tested		**156**	**67**	**42**	**77**	**63**	**49**	**83**	**32**	**138**	**94**	**97**	**50**	**31**	**36**	**14**

* or Buster (believed to carry resistance from the same source)

Table 5 shows the frequencies of pathotypes in 2003, compared with their 2002 values. The 14 isolates tested in 2003 represented 8 different pathotypes.

93% of 2003 isolates, compared with 75% of 2002 isolates, carried the WYV9,17 combination which confers virulence for cultivars such as Brigadier and Savannah. 50% of 2003 isolates carried the combination WYV6,9,17, conferring virulence for cultivars such as Madrigal.

57% of 2003 isolates carried WYV9,CV, which has been associated with virulence for cultivars such as Oxbow, a similar level to that found in 2002.

Pathotypes combining WYV6, WYV9 and WYVCV were uncommon. This combination of virulence factors was provisionally identified in both years and isolates are being tested further.

Table 5. Frequency (%) of pathotypes detected in 2003, with their 2002 values.

Pathotype*	2002	2003
1,2,3,4,6,9,17	6	29
1,2,3,6,9,17	6	7
1,2,3,4,6,7,9,17	3	0
1,2,3,9,17	6	0
1,2,3,4,9,17,CV	31	14
1,2,3,4,7,9,17,CV	0	21
1,2,3,9,17,CV	11	7
1,2,3,4,6,7,9,17,CV	0	7
1,2,3,4,6,9,17,CV	6	7
1,2,3,6,9,17,CV	6	0
1,2,3,4,7,CV	0	7

* excludes variation in virulence for WYRSo, WYRSd and WYRSp.

Isolates from inoculated plots

Five of the 16 isolates tested were virulent on the resistant cultivar Xi19, two on Solstice and two on Spaldings Prolific. The combination WYV6,9,17,CV was detected in two isolates. These isolates are undergoing confirmatory tests.

ADULT PLANT TESTS

Methods

Ten isolates (Table 6) were tested on a set of 62 cultivars in adult plant tests in field isolation nurseries. Seedling tests of the same isolates and cultivars were carried out under standard controlled environment conditions.

Table 6. Isolates tested on adult plant in 2003.

Isolate number	Location	Cultivar	Virulence
00/41	Lincs	Oxbow	1,2,3,4,9,17,CV
02/1	Cambs	Malacca	1,2,3,6,7,9,17
02/4	Cambs	Madrigal	1,2,3,4,6,7,9,17
02/16/10	Cambs	Buchan	1,2,3,6,7,9,17,CV
02/21	Essex	Access	1,2,3,4,6,7,9,17
02/23	Cambs	Riband	1,2,3,4,6,7,9,17
02/49	Scotland	Madrigal	1,2,3,6,7,9,17
02/70	Morley	Robigus	1,2,3,9,CV
02/74	Norfolk	Goodwood	1,2,3,4,6,9,17
02/84	Cambs	Imp	3,4,CV

Results

Results of adult plant tests are shown in Table 7. Seedling test results were used to provide additional information on the specific resistance of cultivars and virulence of isolates. Cultivars have been grouped to facilitate discussion only; the groups are not Diversification Groups. Areas of the table have been highlighted to draw attention to possible variety x isolate interactions. These have no statistical basis.

Group A

These cultivars are characterised by a high level of resistance to all isolates as adult plants. Some are resistant at the seedling stage (R); others show seedling susceptibility to certain isolates, although this is often inconsistent and specific resistances are not usually identifiable (x + APR).

Group B

These cultivars carry the WYR17 resistance, with or without WYR6 and WYR9. Six isolates (02/1 to 02/74) gave high levels of infection on all cultivars (*B1* and *B2*), confirming that they carry the virulence combination WYV6,9,17. In contrast, 00/41 (the original Oxbow isolate) was virulent only on Savannah (*B1*), confirming that this isolate does not carry WYV6.

Infection on *Group B* cultivars inoculated with 02/70 and 02/84 is inconsistent with seedling reaction data and is probably due to contamination from virulent pathotypes in nearby nurseries.

Group C

These cultivars are believed to carry WYRCV, together with other resistances, which have yet to be identified.

Isolate 02/70 gave increased infection on cultivars in *C1*, *C2* (which includes Oxbow, Robigus and Consort) and *C3*. In this respect, it appeared very similar to 00/41 (the original 'Oxbow' isolate). The only indication of a difference between the two isolates was that 00/41 failed to give increased infection on *C3* cultivars (Dart and Shamrock). 02/70 appears to be a less complex pathotype than 00/41, lacking WYV4 and WYV17. This is evidence that these virulences are not required to match the resistance of cultivars in this group.

Isolate 02/84 gave increased infection on *C1* cultivars and Shamrock only and was not virulent on cultivars in the *C2* group.

Cultivars which are specifically susceptible to 'Oxbow-virulent' isolates (*C2*) appear to carry resistance in addition to that of Carstens V itself. Some (e.g. Oxbow and Senator) carry WYR9, associated with the 1B:1R translocation, but others (e.g. Consort and Robigus) do not. Whatever the identity of the additional resistance, it is now matched by isolates such as 00/41 and 02/70, which to date have all carried combined virulence for WYR9 and WYRCV.

The provisional identification of isolate 02/16/10 as carrying combined virulence for Oxbow and WYR6 requires further investigation. In adult plant tests this isolate gave moderate levels of infection on Oxbow and Vivant, but not on other cultivars in the *C2* group.

A total of 6 isolates were identified in seedling tests as carrying WYV7, but only one of these, 02/16/10, gave high infection on Cordiale (*E*). HGCA Recommended List tests have indicated that Cordiale possesses WYR7. These results indicate that the cultivar may carry additional resistances that are not matched by all isolates carrying WYV7.

Isolate 02/84, a relatively simple pathotype identified as WYV3,4,CV, gave, low levels of infection on the previously resistant cultivars Scorpion 25, Xi19 and Warlock 24, as well as on Charger (*Group D*).

Table 7. Adult plant field tests. Percentage leaf area infected with yellow rust (mean of 3 assessments).

	WYR	02/1 1,2,3,6,7,9,17	02/4 1,2,3,4,6,7,9,17	02/21 1,2,3,4,6,7,9,17	02/23 1,2,3,4,6,7,9,17	02/49 1,2,3,6,(7),9,17	02/74 1,2,3,4,6,9,17	02/16/10 1,2,3,6,7,9,17,CV	02/70 1,2,3,9,CV	00/41 1,2,3,4,9,17,CV	02/84 3,4,CV
Group A											
Apostle	2,6, APR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cadenza	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Smuggler	x, APR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tellus	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tonic	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Arran	R	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Option	R	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Parade	R	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0
Buster	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Hunter	2,6, APR	0.0	0.0	0.0	0.0	0.3	0.3	0.0	0.2	0.0	0.0
Lorraine	x, APR	0.0	0.3	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Arminda	R	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0
Chatsworth	R	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.4	0.5	0.0
Malacca	x, APR	0.0	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0
Claire	x, APR	0.0	0.0	0.2	0.5	0.5	0.2	0.2	0.4	0.7	0.0
Istabraq	x, APR	0.0	0.0	0.8	0.0	0.1	0.0	0.0	0.5	0.7	0.0
Richmond	R	0.0	0.2	0.0	0.1	0.8	0.0	0.0	0.0	0.7	0.0
Solstice	R	0.0	0.2	0.0	0.7	0.0	0.1	0.0	0.9	0.0	0.0
Deben	x, APR	0.0	0.0	0.0	0.1	0.0	1.0	0.0	0.4	0.0	0.0
SW Tataros	x, APR	0.0	0.1	0.0	0.0	0.9	1.0	0.0	1.0	0.0	0.0
Pennant	x, APR	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0	0.0	0.0
Boxer	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.0	0.8
Vector	R	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3
Flame	x, APR	0.2	0.5	1.5	0.0	0.0	0.1	0.0	0.0	0.2	0.3
Nijinsky	x, APR	0.0	0.0	0.0	0.0	0.0	0.0	0.2	1.7	0.5	0.0
Gladiator	x, APR	2.0	1.0	0.0	0.1	0.6	0.4	0.0	0.1	0.8	0.0
Group B1											
Savannah	9,17	9.0	9.2	5.2	7.7	4.8	7.8	7.7	5.5	5.8	6.0
Group B2											
Madrigal	6,9,17	12.2	9.0	5.0	11.7	9.5	7.5	9.8	7.5	0.3	1.4
Napier	6,9,17	10.3	7.7	12.3	3.8	7.2	9.0	10.0	5.5	0.2	3.4
Bentley	6,17	12.7	8.8	9.2	6.8	8.5	8.2	6.7	5.2	0.0	4.2
Welford	6,17	3.2	1.4	3.3	1.5	5.5	2.9	3.0	3.4	0.0	0.0
Quest	6,17	4.0	5.5	6.0	1.4	3.2	7.2	4.3	3.2	0.5	1.7
Steadfast	6,17	6.2	0.7	5.8	1.5	5.2	4.7	2.8	2.5	0.2	0.2

	WYR	02/1 1,2,3,6,7,9,17	02/4 1,2,3,4,6,7,9,17	02/21 1,2,3,4,6,7,9,17	02/23 1,2,3,4,6,7,9,17	02/49 1,2,3,6,(7),9,17	02/74 1,2,3,4,6,9,17	02/16/10 1,2,3,6,7,9,17,CV	02/70 1,2,3,9,CV	00/41 1,2,3,4,9,17,CV	02/84 3,4,CV
Group C1											
Carstens V	CV	2.5	1.9	1.2	3.3	2.3	3.2	2.4	8.5	3.7	7.2
Hereward	CV+	1.7	4.5	1.7	1.3	1.8	0.3	0.8	8.0	5.2	5.3
Group C2											
Vivant	CV+	3.2	3.3	4.3	6.2	3.6	1.8	5.8	12.8	13.2	2.4
Oxbow	9,CV+	1.4	0.8	3.0	2.7	3.7	2.5	6.3	12.0	7.3	1.4
Senator	9,CV+	1.5	1.8	1.2	2.5	3.5	3.8	1.5	11.5	8.3	1.0
Wizard	CV+	1.2	0.0	0.5	1.5	2.4	1.3	0.0	9.7	10.0	0.5
Brunel	CV+	3.3	0.2	0.9	1.9	2.3	2.7	1.7	8.7	8.0	1.7
Dickson	CV+	0.5	0.6	2.7	0.0	2.0	2.0	3.3	8.3	6.5	1.5
Robigus	CV+	1.2	0.1	0.2	2.4	2.0	2.7	2.0	7.3	6.8	0.2
Consort	CV+	0.3	0.7	0.5	0.8	2.4	0.7	0.0	5.5	4.5	0.8
Group C3											
Dart	CV+	0.0	0.0	0.0	0.0	0.8	0.0	0.0	4.8	0.8	0.0
Shamrock	?CV	0.0	0.0	0.0	0.8	3.2	0.2	0.0	5.0	0.0	3.2
Group D											
Charger	x, APR	0.0	0.4	0.8	0.7	0.5	0.8	0.0	0.0	0.0	5.3
Scorpion 25	R?	0.2	0.0	0.0	0.0	2.2	0.0	0.3	0.0	0.0	2.7
Xi19.	R?	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.5	0.0	3.5
Warlock 24	R?	1.0	0.0	0.0	0.2	0.9	0.0	0.0	0.0	0.0	1.7
Group E											
Soissons	?3	5.7	0.7	1.0	2.6	5.9	8.4	0.5	7.5	4.3	1.7
Goodwood	?6+	2.4	1.5	2.8	1.9	5.8	1.3	1.3	1.8	0.0	3.8
Einstein	?6+	2.0	5.7	3.4	7.8	2.9	7.2	3.7	2.4	0.0	6.5
Chardonnay	?6	11.7	5.0	9.2	8.3	8.8	8.7	8.8	6.5	0.2	2.2
Cordiale	7	1.2	0.4	3.4	2.0	2.5	1.9	8.0	4.2	0.2	0.3
Tanker	9	7.3	5.5	8.2	4.8	6.8	4.3	3.3	6.3	5.7	0.8
Carlton	9	6.7	6.7	7.5	6.3	5.4	5.0	4.8	4.7	5.5	0.5
Riband	13	5.7	4.3	3.3	3.2	3.3	2.4	1.5	3.3	1.3	0.0
Hobbit	14	6.9	8.5	9.3	10.0	9.8	8.7	6.7	9.2	5.3	10.3
Spaldings	RSp	0.0	0.0	0.0	0.0	1.8	0.0	0.0	3.5	0.0	0.0
Prolific											
Heritage	?	1.5	0.0	0.3	1.5	3.7	1.0	0.8	4.0	0.1	0.0
Tambor	?	2.7	1.7	0.2	2.9	1.3	2.2	1.2	1.5	3.5	0.3
Mercia	?	0.8	0.0	1.0	0.0	0.0	0.0	0.0	2.3	0.0	1.0

CONCLUSIONS

Virulence for Oxbow was identified in 50% of the isolates from the 2003 survey, a similar level to that found in 2003, all of which carried WYV9,17,CV.

The combination WYV6,9,17,CV, first detected in 2002, was found in a small number of 2003 isolates and is still under investigation. The resistant cultivars Solstice and Xi19 appear to be affected by new pathotypes and possible virulence for WYRSp and WYRPa was discovered for the first time. If confirmed, these changes could potentially have implications for current resistant cultivars and resistance sources that are being used in breeding programmes.

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YELLOW RUST OF BARLEY

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Yellow rust of barley was less common in 2003 than in 2002, due to long periods of dry weather during the spring and summer. Isolates exhibited a range of virulence for the differential cultivars, and for a set of additional cultivars.

INTRODUCTION

Yellow rust of barley was not as widespread in 2003 as in 2002. Fewer samples were received probably due to long periods of very dry weather during the spring and summer preventing the disease reaching high levels.

SEEDLING VIRULENCE TESTS OF ISOLATES COLLECTED IN 2003

Methods

19 samples of yellow rust of barley were received in 2003. Isolates were cultured from 13 samples, all of which were tested. The greatest number of isolates tested came from Cambridge and Dundee (Table 1).

Table 1. Locations from which barley isolates were received in 2003.

Region	County	No. of samples received	No. of isolates cultured	tested
East Anglia	Cambridgeshire	6	6	6
East Midlands	Lincolnshire	5	2	2
Yorkshire	Humber	1	0	0
North East	Northumberland	1	0	0
	Cleveland	1	0	0
Scotland	Dundee	5	5	5
TOTAL		**19**	**13**	**13**

The cultivars from which the isolates originated are shown in Table 2. All samples came from winter barley cultivars or breeding lines.

Table 2. Cultivars from which samples of barley yellow rust were collected in 2003.

Source cultivar	Resistance rating (1-9)*	% Area grown#	Number of samples received	Number of samples	
				cultured	tested
Kestrel (w)	3	0.9	1	1	1
Leonie (w)	4	-	1	1	1
Pearl (w)	6	42.4	1	1	1
Regina (w)	2	2.5	4	2	2
Siberia (w)	4	5.6	1	1	1
Vanessa (w)	3	0.6	1	0	0
Angora (w)	2	0	1	0	0
Fighter (w)	7	0	1	0	0
Other cultivars and breeding lines (w)	-	-	8	7	7
TOTAL			**19**	**13**	**13**

(w) = winter cultivar
* HGCA Recommended List ratings for 2003 or most recent where cultivar is no longer recommended (HGCA2003)
Cultivars recommended for 2003 in **bold**.
NIAB seed production statistics for England and Wales for 2003.

Table 3 lists the differential cultivars and additional cultivars that were used in the 2003 seedling virulence tests.

Table 3. Differential cultivars used to test isolates of barley yellow rust in 2003.

Cultivar	BYR factor
Astrix	1
Atem	1
Bigo	2
Varunda	2
Mazurka	2
Triumph	3
<u>Additional cultivars</u>	
Gleam	x
Pearl	x
Fanfare	x
Manitou	x
Optic	x
Derkado	R

x = interacts with isolates in seedling tests, but specific resistance not identified
R = resistant to all isolates in seedling tests

Results

Table 4 shows the virulence frequencies for 1984-2003 (no samples were received in 1996, 1997 or 1998). These figures should be interpreted with caution due to the bias caused by the low incidence of the disease and small number of samples. In 2003, most isolates possessed BYV 1. Three isolates this year showed virulence for BYV2, which has not been detected for the last 2 years.

Isolates also varied in virulence for the six additional cultivars (Table 5). Virulence for Gleam was the most common followed by virulence for Pearl and Fanfare. Derkado remained resistant to all isolates.

Table 4. Percentage frequency of barley yellow rust virulence factors for 1984 – 2003.

	’84	’87	’89	’90	’91	’92	’93	’94	’95	’99	’00	’01	’02	'03
BYV1	100	100	100	100	100	100	100	100	100	100	86	100	100	92
BYV2	100	100	100	0	100	100	100	100	100	100	71	0	0	23
BYV3	86	22	75	0	0	0	0	100	0	100	71	0	50	38
No. of Isolates tested	7	9	4	1	1	2	1	1	3	1	7	3	8	13

Table 5. Frequency of virulence for additional cultivars, 2002 and 2003.

Cultivar	Virulence frequency (%)	
	2002	2003
Gleam	38	100
Pearl	50	77
Fanfare	38	77
Manitou	50	15
Optic	13	31
Derkado	0	0

CONCLUSIONS

Yellow rust of barley was less common in 2003 than in 2002. There is evidence of pathogenic variation within the UK yellow rust population that is not adequately described by the traditional differential cultivars. It is important to ensure that potential new cultivars are assessed for resistance to a fully representative range of isolates.

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BROWN RUST OF WHEAT

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Resistance conferred by genes Lr9, Lr19 and Lr24 remains effective. The resistance genes Lr10, Lr13 and Lr26, which are among the most common in UK cvs, offer little protection in the field when deployed singly. When, however, they are combined with each other or with other Lr genes they can confer good levels of adult plant resistance. Cvs carrying gene Lr37 have shown high levels of field resistance. An isolate from the 2001 survey appears to have increased virulence to the Thatcher-backcross line Lr37 and to some cvs carrying this gene when it is combined with genes L26 and/or Lr10. Disease levels on these cvs are, however, relatively low and there have been no reports in 2003 of increased brown rust infection on commercially grown crops of these cvs. The newly introduced winter wheats Welford, Brompton and Ambrosia carry Lr26. Cv. Claire, which has shown high levels of adult plant resistance and which probably occupies around 20% of the winter wheat hectarage, was quite heavily infected by one isolate in controlled environment tests. This increased virulence needs to be confirmed in the field. The majority of currently recommended winter and spring wheats have resistance effective against the UK pathogen population.

INTRODUCTION

Brown rust was, as in recent years, at a low incidence and where crops were infected disease levels were generally low. This was probably because weather conditions were not conducive to development of the disease. Also, several of the cvs grown commercially carry high levels of resistance. It is estimated that around 35% of the 2003 winter wheat hectarage was sown to cvs with Recommended List (RL) disease ratings of 8 or 9.

Although 33 samples were received, which is above the average for recent seasons, they were all from winter wheat demonstration plots grown at N.I.A.B., Cambridge. They were collected from 31 different cvs and the majority of the leaf samples were infected at low levels.

VIRULENCE FREQUENCIES AS DETERMINED BY GLASSHOUSE SEEDLING TESTS WITH YEAR 2003 ISOLATES

Methods

Isolates of *Puccinia recondita* were cultured from 22 of the samples and tested on three sets of wheat lines: 1) differential cvs which comprise the standard WBR cvs (Table 1); 2) the core set of 'Thatcher' Near Isogenic Lines (NILs) carrying different Lr resistance factors (Table 2); 3) a number of potential new winter and spring wheat cvs (Table 3).

Table 1 * Standard WBR cvs used in tests with 2003 isolates

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

*The differential cvs Huntsman (WBR-5, Lr13), Gamin (WBR-6), Ranger (WBR-8) and Avalon (WBR-9) were not included as their resistances are of the adult plant type.

Table 2 Differential set of 'Thatcher' near isogenic lines used to identify leaf rust virulence

Lr gene	Pedigree
1	Tc6/Centenario
2a	Tc6/Webster
2b	Tc6/Carina
2c	Tc6/Loros
3	Tc6/Democrat
9	Transfer/Tc6
11	Tc6/Hussar
15	Tc5/Kenya W1483
17	Klein Lucero/Tc6
19	Tc7/T4
21	Tc6/R.L.54'06
23	Lee 310/Tc6
24	Tc6/Agent
26	Tc6/ST-1.25
28	Tc6/C77.1
Tc	Thatcher

Table 3 Newly introduced and potential new winter and spring* wheat cvs included in tests with isolates from the 2003 survey

Glasgow	Defender	Exeter
Welford	Dickson	Ambrosia
CPBT W96	Brompton	*CPBT W93
Istabraq	Cordiale	*NSL SW9

Plants were grown in a spore-proofed glasshouse and, following inoculation, were placed in dew simulation chambers at 15^{o}C for 24 h in the dark. They were then transferred to one of two post-inoculation environments, namely a low temperature regime (10^{o}C and 12 h photoperiod) or a high temperature regime (25^{o}C and 16 h photoperiod).

Isolate:cv. interactions were classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4). In cvs with temperature-sensitive resistance factors, interactions were classified as susceptible only if that reaction was expressed at both temperatures. Some of the cvs/lines expressed a mixture of resistant and susceptible infection types to the isolates making classification as susceptible or resistant difficult.

Results

Virulence was identified to four of the standard differential cvs (Table 4) including the susceptible check cv. Armada (WBV-0)

Table 4 Virulence frequencies corresponding to WBR factors present in differential cvs 1994-2003

Cv.	WBR factor	Frequency†							
		1994	1995	1998	1999	2000	2001	2002	2003
Clement	1	0.67	0.55	0.43	0.27	0.82	1.00	0.84	0.73
Fundin*	2	0.64	0.67	0.75	0.32	0.60	0.94	0.56	0.73
Sappo*	3	0	0	0	0	0.08	0	0	0
Halberd*	4	0	0	0	0	0.04	0	0	0
Sterna*	7	0.08	0.11	0.07	0.07	0.61	0.65	0.50	0.68
Armada	0	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Number of isolates tested		39	18	43	22	23	17	14	22

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

*Temperature-sensitive resistance

WBV-1 remains at a high frequency in the population. The corresponding resistance WBR-1 (gene Lr26) has been deployed, often in combination with other Lr genes, in several different cvs over many years. Currently more than 20% of the UK winter wheat hectarage is sown to cvs carrying Lr26 (NIAB certified seed data 2003). Virulence to cv. Fundin (WBR-2), which carries gene Lr17b, has remained at a fairly high frequency in the population over a number of years. This temperature-sensitive resistance was deployed in several commercially grown cvs in the early 1980s but of recently recommended wheat cvs only cv. Riband is thought to carry Lr17b where it is combined with Lr13 (Singh *et al.*, 2001). The increased frequency of WBV-7 isolates in recent seasons is a consequence of the relatively high hectarage of the spring wheat crop sown to cvs Chablis and Shiraz which carry the correponding resistance, WBR-7 (Lr3). Prior to 1998, WBV-7 was identified only occasionally. The resistance factor WBR-7 is not thought to have been carried by any recommended cvs since the winter wheat cv. Sabre in the early 1980s.

Six different WBV-groups were identified (Table 5).

Table 5 Virulence combinations and their frequencies identified from 2003 isolates compared with 1994-2002

	Frequency*							
WBV formula	1994	1995	1998	1999	2000	2001	2002	2003
0	0.30	0.22	0.18	0.50	0.18	0	0.14	0.14
1	0.03	0.11	0.05	0.18	0.09	0.06	0.22	0
2	0	0.22	0.37	0.23	0	0	0	0.09
7	0.03	0	0.02	0	0	0	0	0.05
1,2	0.58	0.34	0.33	0.09	0.04	0.29	0.14	0.09
1,3	0	0	0	0	0	0	0	0
1,7	0	0	0	0	0.09	0	0.07	0.09
1,2,7	0.06	0.11	0.05	0	0.52	0.65	0.43	0.54
1,2,3	0	0	0	0	0	0	0	0
1,2,3,4	0	0	0	0	0.04	0	0	0
1,3,4	0	0	0	0	0.04	0	0	0
Number of isolates tested	39	18	43	22	23	17	14	22

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

WBV-1, WBV-2 and WBV-7 were combined in 54% of the isolates thus making WBV-1,2,7 the dominant form. The increase in WBV-1,2,7 isolates since the year 2000 is associated with the increased frequency of WBV-7 (see Table 4).

Virulence frequencies in the 2003 isolates corresponding to each Thatcher-Lr backcross line are given in Table 6 where they are compared against the previous five years.

Incubation temperature differentially affected the expression of resistance in some, but not all of the Thatcher lines. Lines carrying Lr1, Lr2a, Lr9, Lr19 and Lr24 were resistant at both temperatures although Lr1 and Lr24 have been susceptible to some isolates at 10^{o}C in previous years' tests.

Several genes were more effective at high temperature. The resistances of Lr2b and Lr23 were effective against all isolates at 25^{o}C but were susceptible to some (Lr2b) or all (Lr23) the isolates at 10^{o}C. The resistance of line Lr2c was also more clearly expressed at higher temperatures. Line Lr3 was susceptible to half of the 2003 isolates. Virulence to this gene has, like that to WBR-7, increased in recent years due to the popularity of cvs Chablis and Shiraz. As in previous years, the temperature-sensitive resistance of line Lr3 was more effective than that of cv. Sterna (WBR-7), which also carries this gene. This difference is probably due to the mixed infection types expressed by line Lr3 and cv. Sterna, particulary at the lower temperature, to several of the isolates, making classification as susceptible or resistant difficult. Line Lr26 was susceptible to the same isolates as cv. Clement (WBR-1) which carries this gene. Of the remaining lines, virulences compatible with resistance genes Lr15, Lr17, Lr21 and Lr28 were found at an increased frequency. Prior to 2001 these lines were resistant to the majority of isolates and the increased virulence is difficult to explain. The genes are not thought to be deployed in any currently recommended cvs although some newly introduced cvs (see point 2 below) showed patterns of responses to the 2003 isolates that were very similar to Lr21. Virulence to all these genes has however been identified, at differing frequencies, in various areas of mainland Europe during the period 1996-1999 (Mesterhazy *et al.*, 2000).
Virulence to Lr11, whose resistance is more effective at 10^{o}C, had been at a decreased frequency between 1999 and 2002 but all 2003 isolates carried the corresponding virulence. It must be remembered, however, that all of the samples received in 2003

were from one location so that the virulence combinations identified may not be representative of those carried by the population as a whole.

Table 6 Virulence frequencies corresponding to each Thatcher-Lr backcross line for years 1998-2003

Thatcher Line (Lr gene)	Frequency					
	1998	1999	2000	2001	2002	2003
1	0	0	0	0	0	0
2a	0	0	0	0	0	0
2b	0.17	0.22	0	0.47	0	0
2c	0.52	0.26	0.04	0.53	0	0.23
3	0.07	0	0.29	0.65	0.29	0.50
9	0	0	0	0	0	0
11	0.96	0.49	0.61	0.53	0.29	1.00
15	0.04	0	0.08	0.47	0.29	0.50
17	0.04	0	0.08	0.53	0.22	0.55
19	0	0	0	0	0	0
21	0.02	0	0	0.53	0	0.77
23	0	0	0	0	0	0
24	0	0	0	0	0	0
26	0.43	0.32	0.83	1.00	0.73	0.73
28	0.07	0	0	0.53	0.56	0.73
Tc	-	-	-	1.00	1.00	1.00
Number of isolates	43	22	23	17	14	22

Several of the newly introduced and potential new cvs carry temperature-sensitive resistances, with many expressing mixed reactions to the isolates. There were, however, similarities in the patterns of the responses of some of the cvs to the isolates. These were as follows:

1. Cvs Welford, Brompton and Ambrosia were susceptible to isolates virulent on Lr26 but resistant to those lacking virulence to this gene.
2. Cvs Dickson, CPBT W96, Istabraq and Exeter were susceptible to 17 isolates but expressed resistance to the remainder at 10^{o}C. The Thatcher line Lr21 was susceptible to the same 17 isolates and differed only from the cvs in this group in that it was resistant at both temperatures to the remaining isolates.
3. Cv. Defender has a temperature sensitive resistance which was effective against some isolates at 25^{o}C.
4. The spring wheat NSL SW9 was susceptible to 50% of the isolates but resistant at 10^{o}C to the remainder.
5. CPBT W93 also has resistance that is more effective at 10^{o}C. However this cv. gave very mixed infection types, especially at 25^{o}C, to several of the isolates making classification as susceptible or resistant difficult.
6. The resistance of cv. Glasgow was effective at both temperatures.
7. Cv. Cordiale was susceptible to the 2003 isolates.

FURTHER TESTS ON TEMPERATURE SENSITIVITY

Methods

Winter and spring wheat cvs which have shown high levels of brown rust resistance were grown in a spore-proofed glasshouse until full emergence of the flag leaf. Also included were cv. Huntsman (susceptible check), potential new cvs. and the cv. Thatcher backcross lines carrying the known specific genes Lr10, Lr13, Lr26 and Lr37 which are thought to be the most commonly deployed Lr genes in UK wheat cvs. Two replicates of each cv. were inoculated with one each of the isolates WBRS-03-31 (WBV-1,2,7) and WBRS-03-11 (WBV-1,7).

Isolate WBRS-03-31 was from cv. Napier which is postulated as carrying Lr genes 10, 26 and 37. This highly resistant cv. was infected, albeit at low levels, by isolate WBRS-01-04 in field and controlled environment tests suggesting that there may some breakdown in resistance conferred by Lr37.

Isolate WBRS-03-11 was from a crop of cv. Claire which expresses high levels of adult plant resistance.

Post-inoculation plants were incubated at low (10^{o}C) or high (25^{o}C) temperatures as described previously (Jones and Clifford, 1997).

Seedlings of the majority of cvs included in the adult plant tests were grown in the spoer-proofed glasshouse to the second leaf stage.They were inoculated with the same isolates under the same conditions as the adult plants.

Results (Table 7)

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

Group 1: The overall resistance of the spring wheat cv. Tybalt was effective.

Group 2: The temperature-sensitive resistances of these spring cvs was effective at 10^{o}C although in cv. Paragon, unlike in the other two cvs, it is only expressed at the later growth stages.

Group 3: Several adult plant responses to both isolates were very mixed making classification as susceptible or resistant very difficult. Nevertheless, the cvs appeared to display a mainly resistant infection type at 10^{o}C but, with the exception of cv. SW Tataros, responded differently to the isolates at 25^{o}C. They showed a more susceptible response to isolate WBRS-03-31 cultured from cv. Napier which is postulated as carrying the Lr resistance genes 10, 26 and 37. Unlike the others, cv. SW Tataros was susceptible to both isolates at 25^{o}C. Resistance expressed by adult plants of these cvs at the lower temperature was not effective in seedling adults tests

Group 4: The adult plant resistance of cv. Tellus was effective but only at the high temperature against isolate WBRS-03-31.

Group 5: These cvs were susceptible. Infection types were, however, in most cases, generally higher (3-4) to isolate WBRS-03-11 than to WBRS-03-31 which induced a mixture of resistant and susceptible responses. Although cv. Claire has shown high levels of field resistance, it has become infected by some isolates in controlled environment tests but infection has either been of a mixed type and/or at low levels. Isolate WBRS-03-11, which was cultured from cv. Claire, infected it at much higher levels than seen previously. It therefore appears that there may be increased virulence to this cv., but this needs to be confirmed in the field.

Group 6: This group is comprised of lines carrying: Lr10, commonly deployed in UK and European wheat cvs but which on its own offers little protection; Lr13 whose temperature-sensitive resistance is generally effective at 25°C in these tests but which like Lr10 offers little protection in the field when deployed on its own; Lr26 which was susceptible to both test isolates and to which a high frequency of virulence is present in the pathogen population; and Lr37 whose resistance was effective at 10°C. Only one isolate, WBRS-01-04, has induced a susceptible response on Lr37 at 10°C. This isolate also infects Lr37 in the field, although infection is of mixed types, and it also infects some cvs carrying this gene, albeit at low levels. There is no evidence that there has been further breakdown in resistance conferred by this gene.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Methods

Winter and spring wheat cvs, including those on the HGCA Recommended Lists, potential new cvs, outmoded cvs, the standard differential cvs and cv. Thatcher backcross lines carrying different Lr resistance genes, were sown in each of two nurseries. The nurseries were inoculated with one of two isolates differing in their virulence according to seedling tests. Isolate WBRS-02-15 (WBV-1,2) was sampled from a crop of cv. Claire (from Lincolnshire) which had up to 5% of its flag leaf area infected. In 2002 controlled environment tests it infected adult plants of cv. Claire albeit at low levels (3%). This cv. has shown good levels of field resistance and has a disease rating of 8. Isolate WBRS-01-04 (WBV-1,2,7) was from a crop of cv. Buchan (from Cambridge) and in in 2001 it had infected a number of previously resistant cvs in seedling tests (Jones, 2002). It also infected cvs Access and Buchan (carrying gene Lr37) at relatively high levels in 2002 adult plant tests in the field and in controlled environments.

Results

Winter Wheats (Table 8)

Disease was slow to build up in the nurseries but towards the end of the season susceptible cvs were heavily infected. Cvs within the nursery inoculated with isolate WBRS-01-04 were generally more heavily infected than those exposed to isolate WBRS-02-15.

Table 8 shows, where identified, the WBR factors, the Lr genes, and the resistance type of the cvs tested. With the exception of the standard differential cvs, postulation of the Lr genes is based on:

1) European ring tests between 1996 and 1999 and additional seedling and adult plant tests at the Plant Breeding Institute, Cobbitty, Australia (Winzeler, Mesterházy and Park *et al.*, 2000; (Singh, Park and McIntosh, 2001).
2) Association with stripe rust resistance (WYR) factors (Bayles *et al.,* 2003).

Plants were assessed throughout the season on percentage leaf area infected (Table 8) Note was also made of reaction type classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4). Cvs are grouped within Table 8 according to their known or postulated resistances and their relative susceptibility to the two isolates.

Group 1: This group comprises the standard WBR differential cvs. Isolate WBRS-02-15 infected cv. Clement (WBR-1) at low levels although it was identified as carrying WBV-1 in seedling tests. It may be that this nursery became contaminated with endemic pathotypes lacking WBV-1 thus 'diluting' the isolate introduced artificially. Adult plant resistance conferred by WBR-8 (cv. Ranger) was effective

Group 2: Cvs were highly resistant thus confirming their RL disease resistance ratings of 8 and 9. Seedling tests suggest that cv. Gladiator carries Lr26 but its field response to isolate WBRS-01-04, which carries the matching virulence, suggests it carries additional resistance(s). Cv. Wizard carries yellow (stripe) rust resistance (WYR) factor 9. This resistance is associated with with leaf rust resistance WBR-1 (Lr26). However there is no other evidence to suggest that it. carries Lr26.

Group 3: Members of this group were more highly infected by isolate WBRS-02-15 than by isolate WBRS-01-04 although, with the exception of cv. Istabraq, infection levels were low. Cv. Claire, whose adult plant resistance has been very effective, was infected by isolate WBRS-02-15 at a level similar to that in controlled environment tests when exposed to the same isolate.

Group 4: Cvs Napier, Access, Savannah and Malacca carry Lr37 in combination with one or more other resistance genes. They were infected at slightly lower levels by isolate WBRS-01-04 than in a similar nursery in 2002. However, the infection types were higher (3-4) in 2003 than in the previous year when cvs Access and Napier expressed a mixture of resistant (1-2) and susceptible (3-4) infection types.

Several of the more recently introduced cvs, Arran, Senator, Bentley, Tellus and Victor were relatively heavily infected but none of these is currently recommended.

Spring Wheats (Table 9)

As in the winter nurseries, the susceptible spring wheat cvs exposed to isolate WBRS-01-04 were more heavily infected than those within the nursery inoculated with WBRS-02-15.

The differential cv. Sappo (WBR-3) was susceptible to WBRS-01-04 although it was resistant in seedling tests to the same isolate.

The recommended spring wheats were, with the exception of cv. Chablis, highly resistant and have RL disease ratings of 8 or 9. As mentioned previously virulence to cv. Chablis has increased in recent seasons and this is reflected in its disease rating that is now 6 whereas in 1996 it was 9.

As in previous years' tests with different isolates of the pathogen, the Thatcher-backcross lines Lr9, Lr17, Lr19 and Lr24 were resistant. Lr17 did, however, show moderate levels of a mixed, mainly resistant infection type wheras the other lines showed no visible signs of infection.

Lines Lr1, Lr2a and Lr23 were infected by both isolates but at much lower levels than the other susceptible lines. They had been resistant in seedling tests although in Lr23 resistance was expressed only at 25^{o}C. Lr2b and Lr2c had also been seedling resistant to isolate WBRS-02-15 at 25^{o}C but they were relatively heavily infected in the field. Line Lr20 was also susceptible to both isolates in the field but cv. Sappo (WBR-3) which carries this gene was infected at much lower levels. This cv. has a temperature-

sensitive resistance which had been overcome by both isolates only at 25°C in seedling tests.

Lr3 was heavily infected in both nurseries although it had been resistant as a seedling at 25°C to WBRS-03-11. Cv. Chablis (WBR-7), which carries this gene, was less heavily infected because it has additional adult plant resistance.

Prior to 2002, Lr37, whose resistance is temperature-sensitive, had expressed low levels of a mixed, mainly resistant infection type in field nurseries to all but one isolate. This isolate, WBRS-98-20, infected it at much higher levels but again the infection type was predominantly resistant. In a 2002 nursery Lr37 expressed relatively low levels of a mixed, mainly susceptible infection type suggesting that there may be some breakdown in resistance conferred by this gene. In 2003 field tests Lr37 again expressed a mixed, susceptible reaction but was more highly infected by isolate WBRS-01-04 than by the same isolate in the previous season. This increased infection may, however, be due to the warmer weather in 2003 as the resistance of Lr 37 is temperature sensitive and is less effective at higher temperatures. There have been no reports of commercially grown cvs that carry this resistance on its own, or in combination with other resistance genes, showing increased levels of disease in 2003.

The remaining lines were relatively highly infected by both isolates. They include Lr13 which has been deployed in several UK and European cvs and which on its own offers little protection against current UK pathotypes.

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Table 7 Percentage flag leaf affected and †reaction types of adult plants and seedlings of winter and spring wheats to specific isolates of leaf rust at 10°C and 25°C

Cv. [RL rating]	Postulated Lr genes	ISOLATE						
		WBRS-03-31 ▪(WBV-1,2,7)			WBRS-03-11 ▪(WBV-1,7)			
			Adult Plant			Adult Plant		
		Group	10°C	25°C	Seedling 10/25°C	10°C	25°C	Seedling 10/25°C
Tybalt [9]		1	0	0	R/R	0	0	R/R
NSL SW9		2	0	2	MR/S	0	7	MR/S
CPBT W93			0	4	Mixed	0	13 MS	Mixed
Paragon [9]			0	15	S/S	5R	15	S/S
Heritage [9]		3	15 MR	30 MS	S/S	10 MR	30 MR	S/MS
CPBT W87			20 MR	20	S/S	20 MR	20 MR	S/S
Smuggler [7]			20 R	30 MS	S/S	20 MR	25 MR	S/S
Dart			Trace	30 MS	S/S	Trace	20 MR	MS/MR
SW Tataros			25 MR	35 MS	S/S	18 MR	30	S/S
Tellus		4	20 MS	25 MR	S/S	25 MR	30 MR	S/S
Einstein [6]	(10)?	5	15 MS	25	S/S	8	20	S/S
CPBT W83			22 MS	30	-/-	18	25 MS	-/-
ELS 00-21			20 MS	20 MS	S/S	8	15	S/S
Dickson			12 MS	30 MS	S/S	20	25	S/S
Bentley			20	25	S/S	8	5	MS/MS
Claire [8]			8 MS	6 MS	S/S	15	10	S/S
Huntsman	13		40	42	S/S	40	25	S/S
Lr10		6	38	28	-/-	30	30	-/-
Lr13			32 MS	22 MR	MS/MR	25	22 MR	S/MR
Lr26			28	25	S/S	30	28	S/S
Lr37			25 R	18	-/-	25 R	15	-/-

*Mean of 2 replicates.
†reaction types assessed on a 0-4 scale. Resistant (R: 0-2); Susceptible (S: 3-4)
All reaction types susceptible unless stated.
When more than one reaction type is expressed by a single cv.,
classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant
▪virulence factors identified in seedling tests.

Table 8 †Reaction of winter wheat cvs to specific isolates of *Puccinia recondita* in field isolation nurseries in 2003

Cultivar [RL rating]	Group	WBR	Postulated Lr genes	▪Resistance type	WBRS-01-04 (WBV-1,2,7)	WBRS-02-15 (WBV-1,2)
Clement	1	1	26	OR	18	3
Fundin		2	17b	OR*	21	9
Huntsman		5	13	APR	24	15
Gamin		6		APR	16	9
Sterna		7	3a+	OR*+APR	7	1
Ranger		8		APR	0	0
Avalon		9		APR	29	8
Arina		0	13 ?		48	28
Richmond [9]	2			OR*	0	0
Robigus [9]				OR	0	0
Steadfast			26+	OR	0	0
Wizard[9]			(26)+	OR*	0	0
Dart					0	0
Heritage					0.1	Tr
Gladiator [8]			26+	OR	2 MR	0
Scorpion 25	3			OR*	0	0.4
Goodwood [8]			(10)?	OR*	0	1
Nijinsky [7]					0	1
Claire [8]				APR	0	2
Istabraq [7]					0.2	8
Warlock 24	4			OR*	0.2	0.5
Malacca [7]			10,13(+37?)	APR	1	0.1
Xi19 [7]				OR*	1	0.5
Deben [5]				OR*	2	2
Napier [9]			(10,26,37)	OR*	3MS	0
Savannah [8]			(26,37)	OR	3	0
Hereward [6]			13+	OR	3	1
Access [8]			(10,26,37)	OR	4	0
Dickson				APR	4	0.5MS
Option [6]				*	4	2
Einstein [6]			(10)?		4	2
Solstice [4]				*	6	11
Smuggler [7]					7	0
SW Tataros [8]					7	1MS
Arran				*	8	2
Senator					10	1
Bentley					12	3
Tellus					13	7
Vector			26	OR	15	0
ELS 00- 21					18	3
CPBT W83					19	9
Consort [4]			10,13	APR	22	5
Welford			26	OR	25	1
Soissons				APR	36	18

†Mean of 3 replicates, 2 assessment dates. All reaction types susceptible unless stated.
MR = mixed resistant; MS = mixed susceptible
APR = adult plant resistance; OR = overall resistance; * temperature sensitive resistance.
( ) postulated Lr genes based on links to resistances for stripe rust.

Table 9 †Reaction of spring wheat cvs and Thatcher Lr backcross lines to specific isolates of *Puccinia recondita* in field isolation nurseries in 2003

					ISOLATE	
Cultivar [RL rating]	Group	WBR-	Postulated Lr genes	▪Resistance type	WBRS-01-04 (WBV-1,2,7)	WBRS-02-15 (WBV-1,2)
Sappo	1	3	20	OR*	9	1
Halberd		4	20	OR*	1	Trace
Belvoir [9]	2			OR*	0	0
Paragon [9]				APR*	0	0
Tybalt [9]				OR	0	0
Morph [8]				*	0	0
Wallace [9]				OR	0	0
Ambient				OR*	0	0
Ashby [8]				OR*	0	Trace
NSL SW9				OR*	0	Trace
CPBT W93				OR*	1	2
Imp				APR*	3	1
Chablis [6]			3a+	OR*+APR	6	1
Lr1	3				13	2
Lr2a					12	4
Lr2b					28	23
Lr2c					41	28
Lr3					44	34
Lr9					0	0
Lr11					48	31
Lr13					44	34
Lr14a					33	16
Lr15					44	31
Lr17					17 MR	9 MR
Lr19					0	0
Lr20					37	15
Lr21					36	19
Lr23					9	2
Lr24					0	0
Lr26					41	23
Lr28					29	24
Lr37					14 MS	2 MS
Thatcher					50	39

†Mean of 3 replicates, 2 assessment dates. All reaction types susceptible unless stated.
MR = mixed resistant; MS = mixed susceptible
APR = adult plant resistance; OR = overall resistance; * temperature sensitive resistance.

BROWN RUST OF BARLEY

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Virulences compatible with with the resistances (Rph genes) carried by the differential cvs were at a very high frequency. Only resistance conferred by gene Rph7, which has not been deployed in UK cvs, was effective. BBV-3 was identified at an increased frequency but this is probably due to the bulk of the 2003 samples being collected at one site. BBR-3 is, however, thought to be carried in some current spring cvs in association with other resistances. These cvs together with several other recommended spring barleys show good levels of resistance in the field. The partial resistance in many of the winter cvs. is effective in preventing high infection. None of the current winter barleys appears to carry race-specific resistance.

INTRODUCTION

Brown rust was at lower levels than in recent years. The samples were collected from a range of 36 winter and 2 spring barley cvs. The winter samples were from trial plots grown at NIAB, Cambridge and the spring barley samples were from Hereford.

SEEDLING TESTS WITH 2003 ISOLATES

Methods

Isolates cultured from 29 samples were tested on the standard set of 10 differential cvs which carry different, identified Rph genes for resistance to brown rust (Table 1).

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

	BBR Factor	Gene (Rph)	Ranking for octal notation
Sudan	1	1	1
Peruvian	2	2	2
Estate	3	3	3
Gold	4	4	4
Quinn	5	2+5	5
Bolivia	6	2+6	6
Cebada Capa	7	7	7
Egypt 4	8	8	8
Hord. 2596	9	9	9
Trumpf	10	12	10

Results

Virulences compatible with the resistance factors carried by 9 of the differential cvs were identified (Table 2). Only resistance conferred by Cebada Capa (Rph7) was effective. This resistance gene has not been deployed in UK cvs. BBV-10 remains at a high frequency (90%) in the population It is probable that resistance factor BBR-10, in combination with other resistances, is carried by some of the current spring barleys. BBV-3 has remained at a fairly stable level over a number of years (Table 2), although none of the recently recommended cvs have relied solely on BBR-3 for resistance. Instead, the resistance gene Rph3 appears to be associated with other genetic factors which govern partial resistance as is postulated in cvs Static and Cellar. The most likely explanation for the increased frequency of BBV-3 in 2003 is that nearly all the samples were from one location. The frequency of BBV-5 remains stable and at a high level although there is no evidence that the gene Rph5 has been carried by any commercially important cvs in recent years

Table 2 Frequencies of individual virulences 1993-2003

	Frequency					
BRV - Year	1993	1995	1997	1999	2001	2003
1	1.00	1.00	1.00	1.00	1.00	1.00
2	1.00	1.00	1.00	1.00	1.00	1.00
3	0.17	0.50	0.30	0.36	0.34	0.65
4	1.00	1.00	1.00	1.00	1.00	1.00
5	1.00	0.74	0.88	1.00	0.80	0.90
6	1.00	1.00	1.00	1.00	1.00	1.00
7	0	0	0	0	0	0
8	1.00	1.00	1.00	1.00	1.00	1.00
9	1.00	1.00	0.55	0.50	0.61	0.90
10	0.96	0.94	0.88	0.50	0.61	0.90
No. of isolates	18	49	33	14	41	29

As in recent seasons the pathotypes identified (Table 3) were relatively complex, carrying between 6 (race octal 273) and 9 (race octal 1677) virulence factors. Race octal 273, which lacks virulence factor BBV-3, was at a reduced frequency in 2003. This race has been dominant in recent years and the decline corresponds with the increased frequency of BBV-3 in the population.

Table 3 Races and their frequencies identified from the 2003 isolates compared with representative data from the previous ten years

Race Octal	BBV factors	Frequency					
		1993	1995	1997	1999	2001	2003
273	1,2,4,5,6,8	0	0	0.06	0.43	0.37	0.06
673	1,2,4,5,6,8,9	0	0.02	0.03	0	0	0
277	1,2,3,4,5,6,8	0	0	0.03	0.07	0.02	0
677	1,2,3,4,5,6,8,9	0.06	0.02	0	0	0.07	0
1273	1,2,4,5,6,8,10	0	0	0.24	0	0	0
1277	1,2,3,4,5,6,8,10	0	0	0.18	0	0	0
1653	1,2,4,6,8,9,10	0	0.10	0.09	0	0.12	0
1657	1,2,3,4,6,8,9,10	0	0.14	0.03	0	0	0.06
1673	1,2,3,4,5,8,9,10	0.83	0.37	0.28	0.21	0.22	0.29
1677	1,2,3,4,5,6,8,9,10	0.11	0.35	0.06	0.29	0.20	0.59
No. of isolates		18	49	33	14	41	29

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF BROWN RUST

Methods

Adult plant tests

Spring and winter barley cvs were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included cvs on the HGCA Recommended Lists (RL) of winter and spring barleys, potential new cvs and some of the standard differential cvs. Two replicates of each winter cv. were inoculated separately with each of the following isolates:

Isolate	BBV-	Race octal	Origin
BRS-03-06	1,2,4,5,6,8,10	1673	cv. Eden, Cambridgeshire
BRS-03-35	1,2,3,4,6,8,9,10	1657	cv. Angela, Cambridgeshire
BRS-02-07	1,2,3,4,6,8,9,10	1657	cv. Cannock, Cambridgeshire

The spring barleys were inoculated with each of isolates BRS-03-06, BRS-03-35 and isolate BRS-02-72 (BBV-1,2,3,4,5,6,8; race octal 277; origin cv. Pastoral, Cambridgeshire).

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

Seedling tests

Seedlings of spring and winter barley cvs included in the adult plant tests, plus additional winter barleys, were grown in a spore-proofed glass-house to the second leaf stage. They

were inoculated with the same isolates and under the same conditions as the adult plants. Assessments of infection type, classified on the standard 0-4 scale were made on the first leaf.

Isolate BRS-02-07 had in previous seedling tests induced a susceptible reaction (type 3) on seedlings of the resistant cvs Static, Tavern, Cellar and County although their resistance/s remained effective against this isolate in the field. Isolate BRS-03-35 was cultured from cv. Angela which has expressed high levels of adult plant resistance. The other two isolates, BRS-02-72 and BRS-03-06, were included in tests as they carry differing combinations of virulence factors.

Results

Winter barleys (Table 4)

All cvs were seedling susceptible. None of the current winter barleys appear to carry race specific resistance but rely on partial resistances. As adult plants, cvs expressed a range of quantitative responses but each showed similar disease levels with respect to the different isolates. In several cvs adult plant infection type was mixed. As previously, cv. Angela, again showed a good level of adult plant resistance, being infected at relatively low levels, even though this year's tests included inoculation with isolate BRS-03-35 which was sampled from cv. Angela.

Spring barleys (Table 5)

In Table 5, cvs are grouped on the basis of similarities in their adult plant x isolate interactions. Grouping does not necessarily imply that cvs within a group carry a common resistance factor(s).

Group 1: Only cv. Athena was susceptible, as an adult plant, to all isolates.
Group 2: Cultivars were resistant as adult plants to isolate BRS-03-35 which is the only one lacking virulence to BBV-5. However, their seedling responses to this isolate indicate that they do not carry the resistance factor BBR-5.
Group 3: Adult plants of these cvs were resistant to all isolates. Isolate BRS-03-06, the only one lacking BBV-3, failed to infect any, but isolates BRS-02-72 and BRS-03-35 induced, in most cases, fairly high levels of a resistant infection type. As seedlings the cvs were susceptible to the BBV-3 carrying isolates and although classified as resistant to isolate BRS-03-06 they expressed a mixed infection type to it. It would appear that cvs within this group express a higher infection type (although still resistant) when exposed to BBV-3 pathotypes. It may be that they carry the resistance gene Rph 3 but, as mentioned previously, they also possess other genetic factors contributing to partial adult plant resistance.
Group 4: Cultivars were susceptible as seedlings and adults to isolate BRS-03-06 but their adult plant resistances were effective against the other isolates.
Group 5: Cultivar Cocktail and the newly introduced cv. Feltwell were resistant as adult plants but susceptible as seedlings. They differed however, in that cv. Cocktail expressed a resistant infection type (chlorotic flecks) whereas cv. Feltwell was apparently immune.
Group 6: This group comprises the differential cvs included in the tests. They were, with the exception of Quinn, susceptible to the isolates carrying the corresponding

virulences. Cv. Quinn was, however, resistant as an adult to isolates identified as carrying the corresponding virulence in seedling tests. The adult plant resistance of this differential cv. to some BBV-5 isolates in glasshouse tests has been identified previously (Jones, 2001).

ADULT PLANT FIELD ISOLATION NURSERIES

Methods

Winter and spring barleys were sown during the 2002-2003 season. They included cvs on the HGCA Recommended Lists of winter and spring barleys, some members of the standard set of differential cvs, outmoded cvs and potential new cvs. Spores of isolate BRS-02-07 (race octal 1657), ex cv. Cannock, Cambridgeshire, were introduced artificially into the nurseries. This isolate infected seedlings of some highly resistant cvs, including Static and Cellar, in 2002 glasshouse tests.
Plants were assessed on percentage leaf area infected and on reaction type using the standard 0-4 scale where resistant (R) = 0-2, and susceptible (S) = 3-4.

Results

Winter barleys (Table 6)

Disease levels were much lower than in a similar nursery in 2002. This was probably due to dry weather conditions restricting disease establishment in the early part of the season.

All cvs were classified as susceptible based on reaction types but they displayed a range in levels of disease. Of the cvs included in 2002 and 2003 field tests only Pict and Scylla were infected at similar levels in both seasons. They were also relatively more heavily infected than might be expected from their RL disease rating [7]. The majority of the remainder of the cvs showed disease levels of less than 25% of their 2002 values. As in similar tests in previous years, cvs Angela and Kestrel were among the least heavily infected cvs.

Spring barleys (Table 7)

Reasonable amounts of disease built up on the susceptible spring barleys. Cultivars expressed a range of quantitative, susceptible or resistant responses to the introduced pathotype, with cv. rankings generally confirming those of the previous year's test. With the exception of cv. Prestige, which was relatively more heavily infected than might be expected, cvs also generally conformed to their RL disease ratings.

Cultivars Static and Cellar have previously shown effective field resistance and are thought to carry BBR-3 plus additional resistance(s). They were susceptible as seedlings to isolate BRS-02-07 but expressed only low levels of a mainly resistant infection type to this isolate in the field. However, it appears that the nursery became contaminated with endemic pathotypes as the seedling differential cv. Quinn (BBR-5) was susceptible although it had been resistant to BRS-02-07 in seedling tests. Several other cvs including

Carafe, Drum, Feltwell and Cocktail expressed resistant reactions as they had done to other isolates in glasshouse adult plant tests. Cv. Athena was susceptible in those tests but in the field it was resistant showing moderate levels of a low infection type (1-2).

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Table 4. Percentage flag leaf affected and *reaction types of adult plants and seedlings ( ) of winter barley cvs inoculated with specific isolates of *Puccinia hordei* in glasshouse tests.

Cultivar [RL rating]	Isolate					
	BRS-02-07 (BBV-1,2,3,4,6,8,9,10) Race octal 1657		BRS-03-35 (BBV-1,2,3,4,6,8,9,10) Race octal 1657		BRS-03-06 (BBV-1,2,4,5,6,8,9,10) Race octal 1673	
Colossus [2]	35	(S)	33	(S)	25	(S)
Vanessa [3]	38	(S)	20	(S)	30	(S)
Aquarelle [4]	30	(S)	20	(S)	30	(S)
Camion [5]	20	(S)	25	(S)	15	(S)
Connoisseur [7]	30 MS	(S)	20 MS	(S)	28 MS	(S)
Nocturne	20 MS	(S)	22 MS	(S)	18 MS	(S)
Kingston	10 MS	(S)	15 MS	(S)	15 MS	(S)
Haka [7]	15 MS	(S)	10 MS	(S)	15 MS	(S)
Tallica [6]	28 MR	(S)	25	(S)	25 MS	(S)
Eden [7]	20 MR	(S)	25 MS	(S)	20 MS	(S)
Kestrel [8]	25 R	(S)	20 MR	(S)	18 MR	(S)
Wigwam [7]	20 MS	(S)	10 R	(S)	5 MS	(S)
Angela [8]	10 MS	(S)	3	(S)	10 MS	(S)
Pearl [6]	-	(S)	-	(S)	-	(S)
Regina [7]	-	(S)	-	(S)	-	(S)
Cannock [5]	-	(S)	-	(S)	-	(S)
Scylla [7]	-	(S)	-	(S)	-	(S)
Carat	-	(S)	-	(S)	-	(S)
Siberia [5]	-	(S)	-	(S)	-	(S)
Sequel [5]	-	(S)	-	(S)	-	(S)
Pict [7]	-	(S)	-	(S)	-	(S)
Amarena	-	(S)	-	(S)	-	(S)
CPBT B64	-	(S)	-	(S)	-	(S)
Rattle	-	(S)	-	(S)	-	(S)
Spectrum	-	(S)	-	(S)	-	(S)
Flagon	-	(S)	-	(S)	-	(S)

All adult plant reactions susceptible unless stated.
*(R) resistant = 0-2 type reaction (S) susceptible = 3-4 type reaction
When more than one reaction type is expressed by a single cv.,
classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant

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Table 5 Percentage flag leaf affected and *reaction types of adult plants and seedlings ( ) of spring barley cvs inoculated with specific isolates of *Puccinia hordei* in glasshouse tests.

Cultivar [RL rating]	Group	Isolate BRS-02-72 (BBV-1,2,3,4,5,6,8) Race octal 277		BRS-03-35 (BBV-1,2,3,4,6,8,9,10) Race octal 1657		BRS-03-06 (BBV-1,2,4,5,6,8,9,10) Race octal 1673	
Athena	1	20	(S)	25	(S)	25	(S)
Rebecca [7]	2	25 MS	(S)	5 R	(S)	35	(S)
Toby [4]		30	(S)	10R	(S)	25	(S)
Kirsty [8]	3	5 I	(S)	25 I	(S)	0	(MR)
Drum		5 R	(S)	28 R	(S)	0	(MR)
Prestige [8]		20 R	(S)	20 R	(S)	0	(MR)
Static [8]		20 R	(MS)	20 R	(MS)	0	(MR)
Cellar [9]		15 R	(S)	15 R	(I)	0	(MR)
Carafe [9]		0	(S)	5 R	(S)	0	(S)
Beryllium	4	8 R	(S)	0	(S)	20	(S)
Doyen		20 R	(S)	1 0 R	(S)	25 MS	(S)
Troon [5]		30 R	(S)	30 R	(S)	25	(S)
Feltwell	5	0	(S)	0	(S)	0	(S)
Cocktail [8]		15R	(MS)	15 R	(MS)	5R	(R)
Estate (BBR-3)	6	15	(S)	30	(S)	0	(R)
Trumpf (BBR-10)		4	(MR)	20	(S)	30	(S)
Quinn (BBR-5)		0	(S)	0	(MR)	-	(S)
Hord.2596 (BBR-9)		-	(R)	-	(S)	-	(S)

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

Table 6 Percentage leaf area affected and reactions type* of winter barley cultivars to brown rust in a field nursery in 2003

Cultivar [RL rating]	% Infection	Reaction type†
Colossus [2]	16	S
Vanessa [3]	15	S
Aquarelle [4]	12	S
Pict [7]	10	S
Antelope	10	S
Scylla [7]	9	S
Siberia [5]	8	S
Cannock [5]	8	S
Sequel [5]	7	S
Leonie	6	S
Pearl [6]	6	S
Clara	5	S
Jewel [6]	4	S
Carat [5]	4	S
Pastoral [7]	3	S
Eden	3	S
Camion [7]	3	S
Regina [7]	2	S
Pedigree	2	S
Tallica	2	S
Kingston	2	S
Diamond	2	S
Sumo [8]	2	S
Connoisseur	1	S
Haka [7]	1	S
Swallow	1	S
Kestrel	1	S
Nocturne	1	S
Wigwam	0.5	S
Angela	0.5	S

*Means of 4 replicates
†S = susceptible (3-4 type reaction)

Table 7 Percentage flag leaf area affected and reactions type* of spring barley cultivars to brown rust in a field nursery in 2003

Cultivar [RL rating]	BBR factor	% Infection	Reaction type†
Riviera [6]		23	S
Chalice [5]		23	S
Prestige [8]		19	S
Quinn	5	17	S
Toby		15	S
Troon [5]		15	MS
Trumpf	10	13	S
Rebecca [7]		13	MS
Decanter [6]		9	MS
Simon	3	8	S
Doyen		8	S
Athena		8	R
Optic [6]		6	MS
Cocktail [8]		5	MS
Beryllium		5	MS
Spire [6]		4	MR
Static [8]		4	MR
Cellar [9]		3	MR
Feltwell		3	R
Drum		2	MR
Carafe [9]		2	MR
Kirsty [8]		2	R

*Mean of 4 replicates

†0-2 type reaction – resistant (R) 3-4 type reaction – susceptible (S)

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

MS = mixed susceptible; MR = mixed resistant

CROWN RUST OF OATS

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The spring oat cv. SW Argyle has effective seedling resistance. The winter oat cv. Millennium and the newly recommended Mascani appear to carry the same race specific resistance: virulence to cv. Millenium has increased in frequency in recent seasons. However, both cvs carry additional adult plant resistance effective against some isolates identified as carrying the corresponding virulence in seedling tests. The remainder of the cvs on the HGCA Recommended Lists of winter and spring oats are susceptible.

INTRODUCTION

Only four samples of crown rust were received in 2003 and all were from winter oat trial plots but from three different locations (Table1).

Table 1 Source cvs and geographic origins of 2003 oat crown rust samples.

Cv. [1-9 rating]	County of origin.
Winter oat	
Gerald [6]	Suffolk
SW Dalguise[3]	Co. Down
Buffalo [7]	Co. Down
Breeding Line	Hants

SEEDLING TESTS WITH 2003 ISOLATES

Methods

Isolates were cultured from the samples and inoculated onto seedlings of the International Set of differential cvs as well as cvs on the HGCA Recommended Lists (RL) of winter and spring oats. Post-inoculation plants were incubated at approximately 15^{o}C in the glasshouse and after 14 days were assessed for reaction type on the standard 0-4 scale as resistant (0-2) or susceptible (3-4).

Results

Based on the responses of the 10 differential cvs, isolates were designated race numbers (Table 2) from the International Register of Pathogenic Races of *Puccinia coronata.*

Virulence to the 4 susceptible differential cvs has been identified at a high frequency and race 251, found in 3 samples, has been the dominant form in recent seasons.

Table 2. Races identified from the 2003 oat crown rust samples.

Source cv.	Susceptible differential cvs	Race
Gerald	Appler, Bond, Saia	251
SW Dalguise	Appler, Bond, Saia	251
Buffalo	Appler, Bond, Saia	251
Breeding Line	Appler, Bond, Saia, Anthony	205

Of the RL cvs only the spring oat cv. SW Argyle was resistant to all the isolates. The winter oat cvs Millennium and Mascani responded similarly to the isolates. They expressed a mixed, mainly susceptible infection type to three of the isolates and a mixed, mainly resistant reaction to the other. Cultivar Buffalo, was thought to carry the same resistance as cv. Millennium, based on its interactions with the 2002 isolates. However, this now appears questionable since it expressed susceptible infection types (3-4) to all the isolates, as did the remainder of the cvs.

ADULT PLANT TESTS WITH SPECIFIC ISOLATES OF CROWN RUST IN THE GLASSHOUSE

Methods

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

Isolate	Race	Origin
CRS-03-03	251	cv. Buffalo, Co. Down
CRS-00-13	251	cv. Firth, N.Yorks.

From their reaction on the standard differentials, both isolates were classified as race 251 but they differed in that CRS-00-13 lacks virulence to cv. Millennium whereas CRS-03-03 carries the corresponding virulence.

The plants were inoculated in a settling tower and then placed in dew-simulation chambers at 15^{o}C for 16 h prior to incubation in the glasshouse at approx. 15^{o}C for 16 days. Assessments were made of the percentage flag leaf area infected and of infection type classified on the standard 0-4 scale as resistant (R:0-2) and susceptible (S:3-4).

Results (Table2)

Cultivars are grouped on the basis of similarities in the patterns of their responses to the isolates.

Group 1: The overall resistance of the spring oat cv. SW Argyle was effective. It was apparently immune to isolate CRS-00-13 but showed high levels of a resistant infection type (chlorotic flecks) to isolate CRS-03-03.

Group 2: Cultivars Millennium and Mascani were resistant to both isolates although they were susceptible to isolate CRS-03-03 as seedlings. Reactions expressed to CRS-03-03 were, however, of a higher infection type (more susceptible) than that to CRS-00-13 which also failed to infect both cvs as seedlings. These cvs therefore appear to carry additional partial, adult plant resistance effective against isolate CRS-03-03. In previous tests (Jones, 2000) with different isolates, the resistance of cv. Millennium was overcome at the later growth stages. It has also been susceptible in artificially inoculated field nurseries at IGER. The durability of any adult plant resistance in Millennium must therefore be questioned.

Group 3: The seedling responses of cv. Buffalo to the 2002 isolates suggested it carried the same resistance as cv. Millennium. However it did not give the same pattern of seedling responses as cv. Millennium to the 2003 isolates and was susceptible in these adult plant tests. The remainder of the winter oat cvs were also susceptible.

Group 4: This group comprises the spring oat cvs which were susceptible to both isolates as adult plants. It includes cv. Banquo, whose seedling responses to the 2003 isolates suggested it carried the same seedling resistance as cv. Millennium.

Jones, E.R.L. (2000). Crown rust of oats. *UK Cereal Pathogen Virulence Survey 1999 Annual Report,* pp89-92.

Table 2 †Percentage area of flag leaf infected and *reaction type of winter and spring oats to two different isolates of crown rust race 251

		Isolate			
Cultivar [RL rating]	Group	CRS-03-03		CRS-00-13	
SW Argyle [8]	1	25	R	0	R
Millennium [9~]	2	38	MR	38	R
Mascani [8~]		35	MR	40	R
Buffalo [7]	3	25	MS	35	
Grafton [6]		30		33	
Expression [6]		30		30	
Gerald [6]		28		33	
Jalna [5]		23		33	
Hendon [5]		28		35	
SW Dalguise [3]		35		33	
Ayr [6]		38		38	
Banquo [7]	4	20		20	
Winston [6]		25		28	
Firth [5]		30		30	
Drummer [5]		30		30	
Emotion [4]		30		33	

†Mean of 2 replicates
*reaction type assessed on a 0-4 scale. Resistant (R: 0-2) Susceptible (S: 3-4)
All reactions susceptible unless stated.
When more than one reaction type is expressed by a single cv.,
classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant

RHYNCHOSPORIUM OF BARLEY

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Frequencies of individual virulences were similar to those of recent years. BRV-5, BRV-6 and BRV-8 were at a low frequency, the matching race specific resistances being deployed in few cvs. Several of the current Recommended winter barleys carry BRR-1 and/or BRR-2 and although the corresponding virulences occur widely in the population these cultivars (cvs) express reasonable levels of adult plant resistance. BRR-4, carried by the differential cv. Igri, is postulated, on the basis of their pedigrees, to be carried by several current cvs which in total occupy over 50% of the winter barley hectarage. Again, although the matching virulence is at a high frequency the adult plant resistance of these cvs generally confers good levels of resistance. The resistance of cv. Cannock was effective as a seedling and in the field. The spring barley cvs Beryllium and Rebecca appear to carry BRR-5 and Doyen shows high levels of resistance.

INTRODUCTION

Rhynchosporium was, as in the previous five years, the most severe and widespread disease of barley, with disease levels similar to those of 2002 (CSL/ADAS winter barley disease survey).

Samples of Rhychosporium leaf blotch were received from 28 winter and 16 spring barley samples (Table1) from 13 counties across the UK (Table2). Three samples from cv. Pearl, which previously has shown good levels of resistance, were recorded as having up to 28% of their flag leaf area infected. Samples from other cvs with high disease ratings were infected at generally low levels.

Table 1 Source winter barley cultivars of 2003 leaf blotch samples

Cv.	No. of samples	Cv.	No. of samples	Cv.	No. of samples
Spring cv.				Spring cv.	
Pearl	5	Vanessa	1	Chalice	3
Carat	4	Antonia	1	Cellar	3
Cannock	2	Otter	1	Static	3
Sumo	2	Amarena	1	Riviera	3
Pict	2	Regina	1	Optic	2
Sequel	2	Jewel	1	Prisma	1
Haka	2	Akropolis	1	Kirsty	1
Tallica	1	Siberia	1		

Table 2 Geographic origins of 2003 leaf blotch samples

County of origin	No. of samples	County of origin	No. of samples	County of origin	No. of samples
N.Yorks	11	Cornwall	2	Oxon	1
Cambs	5	Shropshire	2	Avon	1
Hereford	5	Berks	1	Borders	1
Notts	5	Glos	1	Co.Down	6
Norfolk	3				

SEEDLING TESTS WITH YEAR 2003 ISOLATES

Methods

Viable inoculum was prepared from 21 samples and inoculated onto seedlings of the standard differential cvs carrying different, specific resistance genes (Table 3). Post-inoculation plants were incubated in dew-simulation chambers at 15^{o}C for 48h. and then transferred to the glasshouse and incubated at approx. 15^{o}C for 14 days.
Plant responses to infection were assessed as reaction types according to the following conventions which are based on those of Ali and Boyd (1974):
0 = no visible lesion or symptoms
1 = small lesion(s) on margin of leaf blade
2 = narrow band(s) of lesion(s) extending the length of the margins of the leaf blade.
3= well developed lesion(s) on leaf blade
4 = large area(s) of infection.
Reaction types were classified as susceptible (S:3-4), but only if the leaf area infected was greater than 10%, or resistant (R:0-2).

Table 3 Differential test cultivars for *Rhynchosporium secalis*

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

Results

The frequencies of individual virulences identified from the isolates are shown in Table 4 where they are compared with those of previous seasons.

Table 4 Frequencies* of individual virulences, 1993-2003

	BRV-								No. of
Year	8	7	6	5	4	3	2	1	isolates
2003	0	0.62	0.05	0.05	1.00	0.95	0.67	0.67	21
2002	0	0.78	0.01	0.03	0.90	1.00	0.90	0.90	73
2001	0.04	0.80	0.02	0.04	0.94	0.99	0.89	0.89	85
1999	0	0.32	0.16	0.20	0.64	1.00	0.76	0.76	25
1997	0.02	0.37	0.02	0.02	0.96	1.00	0.31	0.31	45
1995	-	0.26	0.13	0.30	0.65	0.91	0.26	0.26	23
1993	-	0.57	0.07	0.12	0.94	1.00	0.68	0.68	69

(*1 represents 100%)

Virulences BRV-1 and BRV-2, although at a lower frequency than in recent years, were identified in 67% of isolates. These virulences appear to be associated as their frequencies have been identical over many years. The resistances BRR-1 and BRR-2 are commonly carried in combination and one or both are present in 9 of the current Recommended winter barleys. Together, these occupy 24% of the winter barley hectarage (NIAB Seedstats, 2003).

BRV-4, that overcomes resistance in the differential cv. Igri (BRR-4), was found in all isolates. The BRR4 resistance has been deployed in several 'popular' winter cvs, e.g. Puffin and Pearl, since the early 1980s so it is not surprising that the corresponding virulence is at a high frequency. However cvs carrying BRR-4 express additional adult plant resistance which has generally conferred good levels of resistance.

BRV-5, found in 1 isolate, has decreased in frequency since 1999. This follows the decline in the winter barley area sown to the outmoded cv. Pipkin (BRR-5) during the latter half of the 1990s. Prior to this BRV-5 had been relatively frequent although there was some fluctuation between seasons, possibly because sample sizes were sometimes small and unrepresentative. Virulence to cv. Osiris (BRR-6) was found in the same isolate. BRV-6 has remained at a low frequency and is usually found in association with BRV-5.

BRV-7 remains at a high frequency in the population, although cv. Pirate which carries the matching resistance BRR-7 carries additional adult plant resistance.

None of the 2003 isolates carried virulence to cv. Digger (BRR-8). BRV-8 was first identified in 1990 when cv .Digger was on the Recommended List (RL) of spring barleys. Since then only two other BRR-8 cvs, Livet and Pewter, have been recommended and neither were widely grown. Consequently BRV-8 has remained at low frequency in the pathogen population.

All the virulence combinations present in the 2003 isolates have been identified previously (Table 5).

Table 5 Virulence factor combinations identified from 2003 isolates

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

1 – susceptible; 0 = resistant

The 'simplest' race, octal 10, found in 1 isolate, carries virulence to cv. Igri (BRR-4) only whilst the most complex, race octal 177, combines virulences to 7 of the differential cvs. As in recent years, Race octal 117 that combines virulence to 5 of the differentials, was the prevalent pathotype.

SEEDLING TESTS WITH SPECIFIC ISOLATES OF *RHYNCHOSPORIUM*

Methods

Winter and spring barleys were grown in a spore-proofed glasshouse until full emergence of the second leaf. They included cvs on the HGCA Recommended Lists (RLs) of winter and spring barleys, newly introduced cvs and members of the standard differential set. Three sets of cvs were inoculated separately with one each of the following isolates:

Isolate	BRV (race octal)	Origin
RS-03-18	3,4 (14)	cv. Antonia, Glos.
RS-03-39	1,2,3,4 (17)	cv. Cellar, Co.Down
RS-03-24	1,2,3,4,5,6,7 (177)	cv. Cellar, N.Yorks

Inoculation and incubation methods were those described previously (Jones, Clifford and Newton, 1996) and plants were assessed as described previously in this report.

Results

Winter barleys (Table 6):

Cultivars are grouped within Table 6 on the basis of similarities in the patterns of their

responses to the isolates and their known resistance factors. Grouping does not necessarily imply that cvs within a group carry a common resistance factor(s).

Group 1: Cvs were susceptible to all isolates. They include the differential cvs Athene (BRR-3) and Igri (BRR-4). Resistance in the latter is often expressed at later growth stages.
Group 2: Host:pathogen interactions suggest that the cvs carry BRR-1 and/or BRR-2. Despite the fact that BRV-1 and BRV-2 have been at high frequency in sample populations for many years, the Recommended cvs within the group have high (resistant) disease resistance ratings [6-8]. It may be that their race specific resistances are more effective at later growth stages or that the cvs carry additional adult plant resistance.
Group 3: Cv. Cannock was resistant to all isolates although previous seedling tests suggested it carried BRR-1 and/or BRR-2. It was however highly resistant in 2002 and 2003 field nurseries.
Group 4: The differential cv. Pirate (BRR-7) was susceptible only to isolate Rs-03-24, the only one carrying the matching virulence.
Group 5: The outmoded cv. Leonie, previously identified as carrying BRR-5, was the only winter barley carrying this resistance factor. This resistance factor, virulence to which is at a low frequency, has been deployed in very few Recommended winter or spring barleys.

Spring barleys (Table 7):

Group 1: These cvs were susceptible as the majority of spring cvs have been over many years. The recommended cvs within the group have fairly low (susceptible) disease ratings [4-5].
Group 2: The differential cv. Armelle (BRR-1) was resistant to isolate Rs-03-18 which does not carry the corresponding virulence. Very few Recommended spring barley cvs have carried BRR-1 which, as mentioned previously, is often associated with BRR-2. Those cvs which have carried these resistances have, however, displayed good levels of adult plant resistance
Group 3: Cvs Beryllium and Rebecca showed a similar pattern of responses to the isolates as the differential cvs La Mesita (BRR-5) and Osiris (BRR-6).
Group 4: Cv. Digger (BRR-8) was resistant to the isolates but did show low levels of a resistant infection type. The newly introduced cv. Doyen responded similarly. In recent years, only cvs Livet and Pewter, have been identified as carrying BRR-8 and neither was widely grown.

ADULT PLANT FIELD ISOLATION NURSERIES

Methods

Winter and spring barley nurseries were grown at a site conducive to the development of leaf blotch during the 2002-2003 season. Cultivars comprised those on the HGCA RLs of winter and spring barleys, potential new cvs, outclassed cvs and cvs carrying known specific resistances that are used as differentials in seedling tests. Disease developed on the susceptible cvs from endemic inoculum.

Results

Winter barleys (Table 8):

Good levels of *Rhynchosporium* leaf blotch built up on the susceptible cvs during the season. Cvs showed quantitative variation in disease levels with cv. rankings not always corresponding with their RL disease ratings. Although several cvs were infected at higher levels than in 2002, the majority gave similar infection levels to the 2001 nursery where inoculum was introduced artificially. The susceptible cvs Sumo and Haka were more heavily infected than in either of these previous years as were the less susceptible cvs Siberia and Sequel. All of these cvs except Sequel have cv. Igri (BRR-4) as an ancestor. As stated previously, resistance derived from cv Igri has been widely deployed in UK winter barleys over many years and is estimated to be carried by cvs currently occupying over 50% of the winter barley hectarage (NIAB Seedstats 2003). It has conferred good levels of adult plant resistance, with the majority of cvs having disease resistance ratings of 7 or 8. It appears, however, that the resistance is becoming less effective in some cvs such as Sumo and Haka. On the other hand, several cvs showed good levels of resistance including cv. Pearl. This cv has resistance that is probably derived from cv. Igri, and it accounts for around 42% of the UK winter barley hectarage. Good resistance was also shown by cv. Cannock whose seedling resistance was effective against isolates carrying a range of virulences.

Spring barleys (Table 9):

Cvs differed in the level of disease they developed but of the currently Recommended spring barleys only cvs. Rebecca and Doyen showed good resistance. Seedling test data suggest that it and cv. Beryllium carries BRR-5 and/orBRR-6, and virulence to these factors did not appear to be carried by the endemic pathotype(s) present in the nursery. The newly introduced cv. Doyen was resistant, as it had been in seedling tests using pathotypes carrying a range of virulence factors. Those isolates lacked only virulence factor BRV-8 and this was also absent in the endemic inoculum infecting the nursery. This suggests either that cv. Doyen carries the resistance BRR-8 or that it combines two or more race specific resistances and that the matching virulences were not combined in the pathotypes.

ADULT PLANT FIELD NURSERY AT SCRI.

Methods

A nursery, comprising cvs from the 2003 HGCA Recommended List of spring barleys, together with winter and spring barleys carrying known specific resistances, was sown during the spring of 2003. Disease was allowed to develop naturally within the nursery.

Results

Assessments of percentage leaf area infected were made throughout the season. Cultivars differed in the levels of disease they developed under natural infection. The most susceptible cvs were very heavily infected. Cultivars Athena, Toby, Optic, Feltwell, Kirsty and Prestige however showed low levels of infection. These cvs are not thought to carry race specific resistance, were heavily infected in a field nursery at IGER and those that are recommended have disease ratings of 4 or 5 (moderately susceptible).Their responses in this nursery are therefore difficult to explain.
Cultivars Beryllium and Rebecca, thought to carry BRR-5 and cv.Doyen, postulated to carry BRR-8, were susceptible but had been resistant in the field at IGER. However based on the responses of the differential cvs La Mesita and Digger the endemic inoculum which infected the SCRI nursery carried the matching virulences BRR-5 and BRR-8.

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Table 6 *Reactions of seedlings of winter barley cultivars to specific isolates of *Rhynchosporium secalis* in glasshouse tests

Cultivar/isolate [RL rating]	Group	RS-03-18 BRV-3,4 (Race octal 14)	RS-03-39 BRV-1,2,3,4 (Race octal 17)	RS-03-24 BRV-1,2,3,4,5,6,7 (Race octal 177)
Otter	1	S	S	S
Kingston		S	S	S
Rattle		S	S	S
Pearl		S	S	S
Camion		S	S	S
Scylla		S	S	S
Haka		S	S	S
Athene (BRR-3)		S	S	S
Igri (BRR-4)		S	S	S
Astrix (BRR-2)	2	R	S	S
Regina [6]		R	S	S
Aquarelle [8]		R	S	S
Nocturne		R	S	S
Colossus [8]		R	S	S
Amarena		R	S	S
Pict [8]		R	S	S
Flagon		R	S	S
CPBT B64		R	S	S
Spectrum		R	S	S
Nocturne		R	S	S
Siberia [7]		R	S	S
Carat [7]		R	S	S
Cannock [8]	3	R	R	R
Pirate (BRR-7)	4	R	R	S
Leonie (BRR-5)	5	R	R	S

*Seedlings assessed on 2nd leaf and classified as resistant (R) or susceptible (S).

Table 7 *Reactions of seedlings of spring barley cultivars to specific isolates of *Rhynchosporium secalis* in glasshouse tests

Cultivar/isolate [RL rating]	Group	RS-03-18 BRV-3,4 (Race octal 14)	Rs-03-39 BRV-1,2,3,4 (Race octal 17)	RS-03-24 BRV-1,2,3,4,5,6,7 (Race octal 177)
Mink	1	S	S	S
Troon		S	S	S
Feltwell		S	S	S
Drum		S	S	S
Athena		S	S	S
Toby		S	S	S
Cocktail [5]		S	S	S
Cellar [4]		S	S	S
Prestige [5]		S	S	S
Kirsty [5]		S	S	S
Static [5]		S	S	S
Chalice [5]		S	S	S
Optic [4]		S	S	S
Spire [4]		S	S	S
Riviera [5]		S	S	S
Decanter [5]		S	S	S
Carafe [4]		S	S	S
Armelle (BRR-1)	2	R	S	S
La Mesita (BRR-5)	3	R	R	S
Osiris (BRR-6)		R	R	S
Beryllium		R	R	S
Rebecca [7]		R	R	S
Digger (BRR-8)	4	R	R	R
Doyen		R	R	R

*Seedlings assessed on 2nd leaf and classified as resistant (R) or susceptible (S).

Table 8 *Percentage leaf infection of winter barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2003

Cultivar [RL rating]	BRR factor	% total leaf area infected
Haka [5]	4	31
Sumo [5]	4	30
Otter		24
Tallica		21
Carat [7]		21
Siberia [7]	2,4	20
Astrix	2	15
Sequel [8]	2	15
Athene	3	14
Pirate	7	14
Igri	4	13
Pastoral [8]	4	12
Aquarelle [8]	2	11
Antelope	2	10
Scylla [6]		10
Regina [6]	2	10
Pict [8]	2	9
Diamond		9
Nocturne	2	8
Clara	5	8
Vanessa [8]	2	8
Spectrum		7
Leonie	5	7
Wigwam	2	6
Swallow	2	6
Jewel [8]	4	5
Camion [7]	4	4
Kestrel	2	4
Angela	2	3
Pedigree		3
Colossus [8]	2?	3
Pearl [7]	4	2
Connoisseur		2
Eden		2
Cannock [8]		0.1

*Mean of 4 replicates

Table 9 *Percentage leaf infection of spring barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2003.

Cultivar [RL rating]	BRR factor	% total leaf area infected
Cellar [4]		29
Carafe [4]		23
Prestige [5]		25
Riviera [5]		22
Drum		21
Toby		21
Optic [4]		21
Feltwell		21
Athena		20
Mink		20
Kirsty [5]		20
Decanter [5]		20
Chalice [5]		20
Static [5]		20
Spire [4]		18
Cocktail [5]		15
Troon [4]		15
Rebecca[7]	5	3
Beryllium	5?	0.5
Armelle	1	0.5
Doyen	8?	0.4
La Mesita	5	0.1
Pewter	8	0.1
Osiris	6	0
Digger	8	0

*Mean of 4 replicates, 2 assessment dates

Table 10 *Percentage leaf infection of spring barley cultivars by *Rhynchosporium secalis* in a SCRI field nursery in 2003.

Cultivar [RL rating]	BRR factor	% total leaf area infected
Beryllium	5?	43
Carafe [4]		43
Thetford		41
Drum		41
Astrix	2	38
Doyen [8]	8?	35
Cellar [4]		37
Cocktail [5]		37
Spire [4]		35
Static [5]		35
Igri	4	35
Pirate	7	34
Rebecca [7]	5	32
Riviera [5]		32
Chalice [5]		26
Digger	8	23
La Mesita	5	17
Prestige [5]		9
Kirsty [5]		7
Feltwell		6
Athene	3	5
Toby		4
Armelle	1	4
Osiris	6	4
Athena		3
Optic [4]		2

SED = 4.29 LSD = 8.46

*Mean of 4 replicates, 3 assessment dates

NET BLOTCH OF BARLEY

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There was a low incidence of net blotch in 2003. It can however be locally damaging to some currently recommended cultivars (cvs), e.g. Pearl and Siberia, that are highly susceptible. The winter barley cvs Sumo, Haka and Cannock may carry resistance factor 4 and cv. Scylla resistance factor 12. Host:pathogen interactions continue to display an unpredictable degree of variability which is not well understood.

INTRODUCTION

Only 11 samples of net blotch were received, reflecting the low incidence of this disease in 2003. They were from a range of winter barleys and locations (Table1). Although a sample was received from the highly resistant cv. Leonie it was infected at a very low level.

Table 1 Source cultivars and locations of 2003 net blotch samples

Source cvs of samples		County of Origin	
Cv. RL [rating]	No.	Cambs	3
Siberia [4]	4	Yorks	1
Pearl [5]	2	Lincs	1
Kestrel	1	Avon	1
Connoisseur	1	Somerset	1
Carat [7]Leonie	1	Dorset	1
Jewel [6]	1	Worcs	1
	1	Norfolk	1
		Tyne & Wear	1

METHODS

Samples were not tested individually but a mixed inoculum was prepared from all the samples.

Adult plant tests

Barley cvs were grown in a spore-proofed glasshouse until full emergence of the flag leaf. They included those cvs on the HGCA Recommended List (RL) of winter barleys

and some unlisted cvs. Two replicates of each cv. were sprayed with the mixed inoculum and then placed in dew chambers in the dark at 15°C for 24 hrs. They were then placed in the glasshouse at approximately 15°C for 12 days. Assessments were made of percentage flag leaf area infected.

Seedling tests

Seedlings of some of the Recommended List (RL) cvs, potential new cvs, as well as the standard set of differential cvs were grown to the second leaf stage. They were inoculated with the same isolate mixture and incubated under identical conditions to the adult plants. Seedling reactions were assessed on the second leaf and classified on a 0-4 scale (Clifford and Jones, 1981) as resistant (R: 0-2) or susceptible (S: 3-4).

RESULTS (Table 2)

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

The mixture of isolates infected seedlings of 3 of the differential cvs, Proctor, CI 9518 and Tenn.61-119. Based on the differential code numbers (Table2) the isolate mixture carried virulence factors 9, 11 and 12. Virulence to these has been at a high frequency in the population for several years. Seedlings of cv. Sequel were resistant as they were in 2001 and 2002 when exposed to different isolate mixtures. Cultivars Amarena and Colossus also expressed seedling resistance to the 2003 isolates.

As adult plants, susceptible cvs were infected at much lower levels than in previous year's tests although they did show a range of quantitative responses. Cultivars Sumo, Haka and Cannock showed no visible signs of infection to the 2003 isolates but were susceptible in 2002 tests. Cultivar Regina was also infected at a much reduced level. This cv. was originally highly resistant when it was included in tests in 1995 when it had a RL resistance rating of 9. Virulence to Regina increased, however, and it was the most susceptible cv. in 2002 tests by which time its resistance rating had fallen to 5. Conversely cvs Scylla and Camion, whose current resistance ratings are 8, were relatively heavily infected. Cultivar Scylla was also more heavily infected in 2001 than might be expected from its RL disease rating although in 2002 it showed very low levels of disease. These differences in disease levels between years are difficult to explain. It may be that some cvs carry race specific resistances which are overcome when the isolate mixture to which they are exposed carries the corresponding virulence factor(s). Based on data from the three most recent years it may be postulated that cvs Sumo, Haka and Cannock carry resistance factor 4 and cv. Scylla resistance factor 12. However since data varies unpredictably from year to year, even under defined and controlled inoculation and incubation conditions, this conclusion remains questionable.

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

Table 2 *Percentage flag leaf area infected and seedling reaction types of winter barley cultivars to a mixture of net blotch isolates in glasshouse tests

Cultivar [RL rating]	Flag leaf % infection	Seedling reaction	Cultivar	Differential code number	Seedling reaction
Kingston	18	S	Flagon		S
Angela	13	-	CPBT B64		S
Connoisseur	15	-	Rattle		S
Scylla [8]	15	S	Spectrum		S
Camion [8]	15	S	Amarena		R
Wigwam	10	-	Pearl [5]		S
Nocturne	8	-	Siberia [4]		S
Antonia [8]	5	-	Sequel [6]		R
Aquarelle [8]	5	S	Carat [7]		S
Vanessa [7]	4	-	Pict [6]		S
Jewel [6]	4	-			
Pastoral [7]	3	-	CI 5401	1	R
Pedigree	3	-	CI 6311	2	R
Leonie	2	-	CI 9820	3	R
Regina [5]	2	S	CI 739	4	R
Eden	2	-	CI 1243	5	R
Colossus [7]	1	R	CI 4795	6	R
Vertige	1	-	CI 4502	7	R
Tallica	1	-	CI 4979	8	R
Sumo [8]	0	S	Proctor	9	S
Cannock [8]	0	S	Code 65	10	R
Haka [7]	0	R	CI 9518	11	S
			Tenn61-119	12	S
			CI 9214	13	R

* mean of 2 plants
Seedlings assessed on reaction type on a 0-4 scale
0-2 type reaction - resistant (R), 3-4 type reaction - susceptible (S)