MILDEW OF WHEAT

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Due to wet weather for much of the spring and summer, sample numbers were low in 2004. Structure of the population was similar to that of 2003. *V2,4b,5,6,8,Ta2* was again the most common pathotype, detected in 52% of the isolates tested. This pathotype overcomes the resistance carried by the majority of currently grown winter wheats. Although most winter cultivars lack effective specific resistance many carry good non-specific resistance. Cordiale, which carries *Mld*, is susceptible to almost 20% of the population, while Scorpion 25 and Xi19 carry resistance matched by less than 10%. Isolates virulent on Robigus, which may also carry *MlAx*, were again detected at a low level although no samples were received from Robigus and resistance remains effective in the field. The spring cultivar Tybalt was resistant to all isolates.

INTRODUCTION

As wet weather prevailed for much of the spring and summer, resulting in variable levels of disease, sample numbers were low. A dry period later in the summer led to an increase in disease levels in susceptible varieties of winter wheat. Mildew levels tended to be higher on the eastern side of the UK – from Scotland down to East Anglia – but there was also occasional infection in western and south-western areas of England.

Robigus maintained its position as the most resistant winter wheat variety, although occasional virulent isolates were obtained in the Survey. Xi19 also remains resistant and the new variety Glasgow appears to have good mildew resistance. Popular varieties Claire, Option and Solstice are susceptible to mildew infection, as is the newcomer Bentley.

METHODS

150 samples of infected leaves were received in 2004. 63 samples failed to produce viable conidia, but 135 isolates obtained from single pustules were cultured from the remaining 87 samples and tested. The tested isolates were collected from seven locations (Table 1).

Table 1. Source locations of leaf sample isolates in 2004.

	No. of isolates tested		No. of isolates tested
NIAB, Cambridge	78	Callow, Herefordshire	3
Berwick, Northumberland	21	High Mowthorpe, Yorks.	2
Quiddenham, Norfolk	18	Hemingby, Lincs.	1
Caythorne, Lincs.	12		
TOTAL			**135**

Table 2 shows the 32 winter wheat cultivars and four spring cultivars from which the tested isolates were derived.

Table 2. Source cultivars of 2004 test isolates.

	No. of isolates		No. of isolates		No. of isolates
Winter cultivars					
Brompton	13	Solstice	3	Smuggler	2
Option	11	Bentley	2	Soissons	2
Ambrosia	9	Cordiale	2	Steadfast	2
Atlanta	9	Deben	2	Welford	2
Exeter	9	Dickson	2	Wizard	2
Claire	8	Gladiator	2	Access	1
Defender	5	Hereward	2	Consort	1
Einstein	5	Istabraq	2	Malacca	1
Glasgow	4	Napier	2	Robigus	1
Richmond	4	Nijinsky	2	Tanker	1
Xi19	4	Scorpion 25	2		
Spring cultivars					
Ashby	4	Chablis	4	Paragon	4
Belvoir	4				
TOTAL					**135**

Random samples were also collected from the air spora by exposing seedlings of the susceptible cultivar Cerco at eight locations in Cambridgeshire and Suffolk during June. 241 single colony isolates cultured from the resulting infections were tested.

Isolates were tested for virulence by inoculation onto detached leaf segments of differential cultivars using a spore-settling tower. The differential cultivars used for virulence tests in 2004 are shown in Table 3.

Winter cultivars Einstein, Robigus, Cordiale and spring cultivars Morph, Tybalt and Equation were also included in some tests, representing cultivars of current interest or unknown resistance.

Table 3. Differential cultivars used to determine virulence factors.

Differential cultivar	European code	Resistance factors
Cerco	none	None
Galahad	Pm2	*Pm2*
Chul	Pm3b	*Pm3b*
Armada	Pm4b	*Pm4b*
Flanders	pm5	*pm5*
Brimstone	Pm2, Pm6	*Pm2, Pm6*
Clement	Pm8	*Pm8*
Amigo	Pm17	*Pm17*
Maris Dove	Mld	*Mld*
Brock	Pm2, MlTa2	*Pm2,* Unknown
Mercia	Pm5, MlTa2	*Pm5,* Unknown
Tonic	MlTo	*Pm2,Pm3d,*Unknown
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

RESULTS AND DISCUSSION

Virulence frequencies

Virulence factors *V2* and *V4* were detected in all isolates tested in 2004 (Table 4), whilst only a single isolate from Over lacked *V6*. Factors *V8* and *VTa2* were also common in all populations, and were detected in at least 90% of isolates tested, whilst approximately 90% of isolates were virulent for *pm5*. Virulence levels for Soissons were variable, ranging from 72% at Harston to 95% at Stapleford.

Levels of virulence for Tonic and Broom were also variable. Virulence was detected in 28% of leaf isolates and 25% of Cherry Hinton and Over populations, but in only 8% of Harston isolates and was absent at Stapleford. Levels of *Vd* varied from 9% in Suffolk to 25% at Cherry Hinton. Virulence for Axona was detected infrequently in most populations and was absent from Stapleford. Frequencies for *Vd, VTo, VBr* and *VAx* are often correlated; isolates carrying virulence for Axona always infect Maris Dove and Broom, and frequently Tonic.

Levels of *VSi, VSo, V3b, V17* and *VSh* were low in all populations. No currently grown cultivars carry *Pm3b* or *Pm17* resistance factors, and *MlSi* and *MlSo* are found only in spring cultivars. Shamrock is no longer grown.

Table 4. Frequency of wheat mildew virulence factors in isolates collected from leaf samples and air spora in 2004.

	% Frequency of virulence factors								
	Leaf isols	Air-borne spore isolates							
Virulence factor		Stapleford, Cambs.	Cherry Hinton	Over, Cambs.	Cambridge	Longstanton, Cambs.	Ely, Cambs.	Harston, Cambs.	Suffolk
2	100	100	100	100	100	100	100	100	100
3b	2	0	5	5	5	8	9	3	3
4b	100	100	100	100	100	100	100	100	100
5	90	90	90	88	85	83	100	87	94
6	100	100	100	98	100	100	100	100	100
8	98	100	95	100	97	96	100	97	97
17	14	0	0	2	3	0	0	3	0
d	21	16	25	24	19	13	22	13	9
2,Ta2	95	90	95	100	100	96	100	97	97
To	28	0	25	24	18	17	17	5	17
Br	28	0	25	25	21	17	17	8	17
5,Si2	5	5	11	8	5	0	23	3	6
So	4	5	0	5	3	0	22	0	0
Ax	13	0	10	12	8	8	4	3	6
Ss	88	95	79	78	89	91	96	72	93
Sh	1	0	5	0	0	0	0	3	0
Number of isolates tested	**135**	**20**	**20**	**41**	**39**	**24**	**23**	**39**	**35**

Virulence frequencies in 2004, shown in Table 5, were similar to those reported in previous years. Virulence factors *V2, V4b, V6* and *V8* were again detected in all, or almost all of the isolates tested. These virulences correspond to the resistances carried by the majority of winter wheat cultivars currently grown. As in 2003, virulence for *pm5* and *MlTa2* was common despite the lack of selection. *VSs* continued to decrease slightly, as Soissons becomes less popular. Virulence factors *Vd*, *VTo* and *VBr* were present in approximately 20% of the isolates, a level similar to that in 2003. *VAx*, *VSi2*, *VSo*, *V3b* and *V17* were less frequent, detected in less than 10% of isolates. As Shamrock is no longer a popular cultivar, a reduction in selection pressure is probably responsible for the decrease in the observed frequency of *VSh*.

Table 5. Frequency of wheat mildew virulence factors in leaf samples collected in 1996-2004.

	Frequency of virulence factors								
Virulence factor	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003#**	**2004#**
2	100	100	100	100	100	100	99	100	100
3b	3	4	1	2	1	4	6	7	4
4b	93	98	100	99	99	100	100	100	100
5	93	95	88	91	88	90	89	92	90
6	96	99	100	100	99	100	100	100	99
8	96	98	97	99	97	98	98	94	98
17	15	16	8	22	2	9	13	4	6
d	33	26	18	6	12	25	24	18	18
2,Ta2	92	93	86	97	96	95	99	96	97
To	29	29	16	16	5	24	20	20	20
Br	32	30	16	15	8	24	27	20	21
5,Si2	32	21	17	20	8	8	15	6	6
So	15	15	10	6	4	6	11	4	4
Ax	24	20	7	1	1	10	8	8	9
Ss			65	57	74	82	93	90	86
Sh				3	0	4	16	8	1
Number of isolates tested	**265**	**313**	**328**	**187**	**148**	**286**	**165**	**209**	**376**

includes isolates from leaf samples and air-borne spores

Frequency of pathotypes

V2,4b,5,6,8,Ta2 was again the most commonly detected pathotype in all populations, albeit at varying levels (Table 6). This pathotype was present in at least 60% of populations at Stapleford, Harston and Suffolk but only occupied 35% of the Cherry Hinton population. Other pathotypes were also detected at varying levels e.g. *V2,4b,5,6,8,Ta2,Si2,So* was present in 17% of the isolates from Ely but absent from Longstanton, Harston and Suffolk. The population at Cherry Hinton was more complex than other populations, with the leaf isolates producing fewer pathotypes.

Table 6. Frequencies of the most commonly identified pathotypes in isolates derived from leaf samples and air spora 2004, as defined by the factors in Table 3, with the exception of MlSs (Soissons) and MlSh (Shamrock).

	Frequency of pathotypes (%)								
	Leaf isols	Air-borne spore isolates							
Pathotype		Stapleford, Cambs.	Cherry Hinton	Over, Cambs.	Cambridge	Longstanton, Cambs.	Ely, Cambs.	Harston, Cambs.	Suffolk
2,4b,5,6,8	1	10	5	0	3	4	0	3	3
2,4b,6,8,Ta2	4	10	10	5	3	13	0	5	6
2,4b,5,6,8,Ta2	49	60	35	49	54	50	39	67	66
2,4b,5,6,8,Ta2,To,Br	10	0	10	7	8	4	13	3	11
2,4b,5,6,8,Ta2,Si2	1	0	5	0	3	0	0	0	0
2,4b,5,6,8,Ta2,Si2,So	2	5	5	2	3	0	17	0	0
2,4b,5,6,8,d,Ta2	3	15	15	10	10	4	17	10	0
2,4b,5,6,8,d,Ta2,To,Br,Ax	6	0	0	7	3	8	4	3	3
2,3b,4,5,6,8,Ta2	0	0	5	5	3	8	9	3	3
Number of pathotypes	33	7	14	16	17	13	9	13	10
Number of isolates tested	135	20	20	41	39	24	23	39	35
Ratio no. pathotypes/no. isols	0.24	0.35	0.70	0.39	0.44	0.54	0.39	0.33	0.29

Table 7 shows the pathotype frequencies for 1995 to 2004. The frequency of the most common pathotype *V2,4b,5,6,8,Ta2*, was higher than in the previous three years. This pathotype is capable of overcoming the specific resistance of the majority of currently grown winter cultivars. Only Cordiale, Scorpion 25, Xi19 and Robigus are resistant to *V2,4b,5,6,8,Ta2*.

Table 7. Frequencies of the most commonly identified pathotypes in isolates, 1995-2004, as defined by the factors in Table 3, with the exception of MlSs (Soissons) and MlSh (Shamrock).

	Frequency of pathotypes (%)									
Pathotype	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003#**	**2004#**
2,4b,5,6,8	8	4	3	9	<1	2	1	0	<1	2
2,4b,6,8,Ta2	3	1	2	6	5	8	5	2	5	5
2,4b,5,8,Ta2	2	1	<1	0	0	1	0	0	0	<1
2,4b,5,6,8,Ta2	38	35	42	38	57	61	41	36	41	52
2,4b,5,6,8,Ta2,To,Br	6	4	7	5	9	1	10	8	10	8
2,4b,5,6,8,Ta2,Si2	4	6	4	5	11	2	1	1	0	<1
2,4b,5,6,8,Ta2,Si2,So	8	4	7	4	2	2	3	2	1	2
2,4b,5,6,8,d,Ta2	5	5	3	6	2	7	12	10	4	6
2,4b,5,6,8,d,Ta2,To,Br,Ax	3	6	10	1	<1	1	5	1	6	5
2,3b,4,5,6,8,Ta2	0	1	1	0	0	<1	2	<1	4	2
Number of pathotypes	**57**	**59**	**44**	**35**	**22**	**37**	**44**	**49**	**64**	**52**
Number of isolates tested	**265**	**313**	**328**	**187**	**148**	**286**	**165**	**209**	**389**	**376**
Ratio no. pathotypes/no. isols	**0.22**	**0.19**	**0.13**	**0.19**	**0.15**	**0.13**	**0.27**	**0.23**	**0.16**	**0.14**

includes isolates from leaf samples and air-borne spores

The trend towards the detection of fewer pathotypes, corresponding to the increase in frequency of the dominant pathotype, continued.

Complexity of isolates

The majority of isolates tested carried six or more virulence factors, as shown in Table 8. The variation in the number of pathotypes with six factors reflects the variation in the frequency of the most common pathotype. Fewer isolates carried six factors at Cherry Hinton (35%) but more isolates carried seven virulence factors. A larger number of isolates carried eight virulence factors at Ely. However, as some sample numbers were small this variation may not be significant. No isolate carried fewer than four virulence factors and few carried more than ten.

Table 8. Number of virulence factors in the wheat mildew populations derived from leaf samples and air spora in 2004.

	Frequency of isolates with varying numbers of virulence factors(%)								
	Leaf isols	Air-borne spore isolates							
Virulence factor		Stapleford, Cambs.	Cherry Hinton	Over, Cambs.	Cambridge	Longstanton, Cambs.	Ely, Cambs.	Harston, Cambs.	Suffolk
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	1	0	0	0	3	0	0	3	0
5	7	20	20	5	8	21	0	8	14
6	59	60	35	56	56	58	43	72	66
7	5	15	20	15	13	8	17	13	0
8	13	5	10	12	13	4	35	3	14
9	3	0	5	2	5	0	0	3	0
10	11	0	10	7	3	8	1	0	3
11	1	0	0	2	0	0	0	0	3
12	0	0	0	0	0	0	0	0	0
Number of isolates tested	**135**	**20**	**20**	**41**	**39**	**24**	**23**	**39**	**35**

The number of virulence factors carried by 2004 isolates was similar to 2003 (Table 9). The population, having acquired virulence factors corresponding to resistance carried by the majority of cultivars grown, now appears relatively stable. Selection pressure for the dominant pathotype (carrying six virulence factors) outweighs selection for additional factors carried by cultivars grown on a limited area only.

Table 9. Number of virulence factors in the wheat mildew population, 1997-2004.

Number of virulence factors*	Frequency of isolates with each number of virulences (%)							
	1997	1998	1999	2000	2001	2002	2003	2004
0	0	0	0	<1	0	0	0	0
1	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0
3	0	0	<1	1	0	0	<1	0
4	1	2	0	1	2	<1	2	<1
5	7	18	7	13	8	11	10	10
6	45	44	59	63	47	44	57	58
7	9	15	16	13	15	18	9	10
8	16	11	13	5	15	12	12	12
9	4	4	2	2	4	6	2	2
10	13	5	3	2	7	7	7	7
11	2	0	0	0	0	1	0	<1
12	3	2	0	<1	1	<1	1	0

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

Infection of winter and spring wheat cultivars

The majority of winter cultivars tested during trials in 2004 are potentially susceptible to over 90% of the mildew population (Table 10). 86% of isolates tested were virulent for Soissons whilst only Cordiale, Scorpion 25, Xi19 and Robigus carry effective specific resistance. Robigus remained the most resistant winter cultivar, susceptible to less than 1% of the population. However, many currently grown cultivars carry good non-specific resistance e.g. Malacca, which though potentially at risk from 100% of the population, has a rating of 7. The new cultivars Defender and Glasgow are potentially at risk from 100% and 98% respectively of the population yet both, with ratings of 8, carry good field resistance. Claire, (at risk from 100% of population, rating 4) in contrast, does not have effective specific resistance and its non-specific resistance is poorer than most other modern cultivars. Whether the ratings of 7 or above for Cordiale, Scorpion 25, Xi19 and Robigus are the result of good specific or non-specific resistance is unknown. This will only become apparent if the level of virulence for the specific resistance carried by these cultivars increases. Should these cultivars become widely grown, an increase in virulence is likely.

Spring cultivars Paragon and Wallace lack effective specific resistance but both carry good non-specific resistance (rating 7 and 9 respectively). Other spring cultivars in trials carry resistance matched by only a small proportion of the population e.g. Morph is at risk from only 3% of isolates tested in 2004. Tybalt remained resistant to all isolates.

Table 10. Proportion of mildew isolates able to infect wheat cultivars in HGCA Recommended List trials in 2004. (2005 Recommended List cultivars in **bold**; mildew resistance ratings in brackets.)

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Winter			
Atlanta (5)	100	**Wizard (7)**	99
Bentley (4)	100	**Access (7)**	98
Claire (4)	100	**Ambrosia (6)**	98
Defender (8)	100	**Brompton (4)**	98
Exeter (5)	100	**Gladiator (7)**	98
Hereward (5)	100	**Glasgow (8)**	98
Istabraq (5)	100	**Napier (6)**	98
Solstice (4)	100	**Savannah (7)**	98
Consort (6)	99	Senator (6)	98
Dart (5)	99	Steadfast (6)	98
Deben (6)	100	**Tanker (6)**	98
Dickson (5)	100	**Welford (6)**	98
Malacca (7)	100	**Einstein (7)**	90
Nijinsky (6)	100	**Soissons (7)**	86
Option (4)	100	**Cordiale (7)**	19
Riband (6)	100	Scorpion 25 (8)	9
Richmond (5)	100	**Xi19 (8)**	9
Smuggler (7)	100	**Robigus (9)**	<1
Spring			
Paragon (7)	100	CPBT W100 (4)	9?
Wallace ((9))	100	Jester ((5))	9?
Chablis (5)	21	**Belvoir ((5))**	6?
Equation ((2))	9	**Morph ((8))**	3
Ashby ((7))	9?	**Tybalt ((9))**	0
Byron ((6))	9?		

Resistance factors of new cultivars

The virulence frequencies for the additional cultivars included in 2004 tests are shown in Table 11. Virulence for Einstein differed in the two sets of samples. While 96% of the air spora carried virulence for Einstein only 74% of the leaf isolates were virulent. Although susceptible to a large part of the population, Einstein also carries non-specific resistance.

Table 11. Infection levels on additional cultivars included in differential tests in 2004

Cultivar	Percentage number of virulent isolates	
	Leaf samples	Air spora
Einstein	74	96
Cordiale	20	19
Robigus	0	<1
Morph	5	1
Tybalt	0	0
Equation	18	18

Virulence for other cultivars included in tests in 2004 was similar in both sets of samples. Present in 19% of air spora, it seems likely that virulence for Cordiale will increase in frequency should the cultivar be grown widely. As only two leaf isolates were derived from infection on Cordiale, the 20% virulence frequency demonstrates that virulence for Cordiale already occurs on cultivars other than Cordiale. It is possible that the spring cultivar Equation, like Cordiale, carries *Mld*.

Table 12. Specific mildew resistance factors in wheat cultivars (2005 Recommended List cultivars in **bold**).

None	*Pm2,4b,6*	*Mld*
Atlanta	**Consort**	**Cordiale**
Defender	Dart	
Exeter	**Deben**	*Mld*?
Hereward	**Dickson**	Equation (S)
Solstice	**Malacca**	
Paragon (S)	**Nijinsky**	*MlAx*
	Riband	Scorpion 25
Pm2	**Richmond**	**Xi19**
Wallace (S)	**Wizard**	**Ashby (S)**
		Byron (s)
Pm2+?	*Pm8*	CPBT W100 (S)
Einstein	**Ambrosia**	Jester (S)
	Brompton	
Pm2,Pm4b	**Glasgow**	*MlAx+?*
Claire	Steadfast	**Robigus**
Bentley	Welford	
Istabraq		*MlBr*
	Pm4b,Pm8	**Chablis (S)**
Pm2,6	Senator	
Option		*Pm2,MlBr*
Smuggler	*Pm4b,Pm6,Pm8*?	**Belvoir (S)**
	Tanker	
		Mld,MlSi2?
	Pm2,Pm4b,Pm6,Pm8	**Morph (S)**
	Gladiator	
	Napier	MlSs
	Savannah	**Soissons**
	Pm2,Pm4b,Pm8 (Pm6?)	Rx?
	Access	**Tybalt (S)**

(S) Spring wheat

No new resistances were detected in novel cultivars in 2004 (Table 12). As in 2003, isolates infecting Robigus also carry virulence for Axona so it seems likely that Robigus carries *MlAx* together with additional unknown virulence. The resistance carried by Tybalt remains unknown.

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MILDEW OF BARLEY

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With wet weather prevailing for much of the spring and summer, 2004 was not an epidemic year for mildew and leaf sample numbers were low. Samples were collected from air-borne spores in Suffolk and Cambridgeshire. Virulence factors *Vra*, *Vh*, *Vg*, *V(CP)*, *VLa*, *Va12*, *Va7*, *V(Ab)* and *Va1* were again detected at high levels, whilst *Va6*, *Va9*, *Va13* and *Va3* occurred at low levels. Variation between air-borne spore samples may be due to the small sample size assayed, or the influence of locally grown cultivars. Virulence frequencies were similar to 2003 although *Vk*, for which there is currently no selection, continued to decrease. The majority of pathotypes carried nine virulence factors although a few isolates with fewer than four factors were detected in air-borne spore samples. *Vh,Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1* were detected in 54% of mildew isolates tested. This pathotype is virulent for all of the currently recommended winter barleys except Vanessa and Sequel, and is virulent against the popular spring cultivar, Optic. The majority of winter barley cultivars are potentially susceptible to over 90% of the mildew population, although only 12% of the population is virulent against Sequel, Saffron and Kingston. Many cultivars, however, carry an effective non-specific resistance. Amarena for example was resistant to all isolates tested. The majority of spring cultivars carry *mlo* resistance, which remains effective in the field. Fewer partially *mlo*-virulent pathotypes were detected in 2004 than in previous years. Doyen, newly recommended for 2005, is the first cultivar carrying *Mla3* to achieve this status.

INTRODUCTION

The relatively mild winter ensured the successful survival of inoculum, but conditions were very changeable thereafter with wet weather prevailing for much of the spring and summer. Accordingly, 2004 was not an epidemic year for mildew and sample numbers of infected material were low.

Infection in winter barley was most severe in Scotland and in the east of England, but occasional high levels were also reported in the south and south-west. The new variety Amarena appears to have very good mildew resistance; Flagon and Rattle also appear to be resistant. Conversely, newcomers Colossus, Nocturne and Saffron are susceptible to infection.

Infection in spring barley was high in Scotland, but otherwise mildew distribution was more closely correlated to host variety than to geographic location.

The *mlo* resistance present in many spring barleys, including new varieties NFC Tipple, Henley, Toucan, Minstrel, Westminster, Power, Waggon, is still very effective although partially *mlo*-virulent isolates have occasionally been obtained. In addition to the susceptible Optic cultivar, new varieties Tocada and Wicket appeared to be fairly susceptible.

METHODS

Virulence survey

80 samples of infected leaves were received in 2004, the lowest number for many years. 138 single colony isolates were cultured and tested from 63 samples (17 samples failed to produce any viable conidia). The locations from which the tested isolates were collected are shown in Table 1.

Table 1. Locations from which tested isolates were collected in 2004.

Location	Number of isolates	Location	Number of isolates
NIAB, Cambridge	121	Baumber, Lincs.	2
Llancayo, Monmouthshire	4	Limarady, NI	2
SAC, Edinburgh	4	Strabane, NI	2
West Newton, Norfolk	3		3
Total number of isolates tested			138

The isolates were collected from 18 winter cultivars and 19 spring cultivars, including six *mlo*-carrying cultivars (Table 2). Seedlings of the susceptible cultivar Golden Promise were exposed to the air spora at eight locations in Cambridgeshire and Suffolk, and single colony isolates were cultured from the resulting infection.

Table 2. Cultivars from which tested leaf isolates were collected in 2004.

Spring cultivars

	isolates		isolates		isolates
Decanter	12	Carafe	2	Tocado	2
Riviera	10	Cocktail	2	Toucan	2
Golden promise	5	Doyen	2	Wicket	2
Apex	5	Kirsty	2	Henley	1
Optic	4	Oxford	2	Troon	1
Rebecca	4	Spire	2	Westminster	1
Static	4				

Winter cultivars

	isolates		isolates		isolates
Regina	10	Haka	4	Spectrum	3
Rattle	8	Kingston	4	Cannock	2

Siberia	6	Nocturne	4	Carat	2
Colossus	5	Pearl	4	Flagon	2
Aquarelle	4	Pict	4	Scylla	2
CPBT W64	4	Camion	3	Sequel	2

The cultivars used to determine which virulence factors were present in isolates, together with their associated resistance factors are shown in Table 3. These cultivars consititute the standard list of differential genes used to screen mildew races.

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

Cultivar	Resistance genes	Barley Mildew Resistance Factor
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

Winter barley cultivars Vanessa, Sumo, Oxbridge and Amarena and the spring cultivars Kirsty, Rebecca, Cocktail, Doyen, Tocado and Macaw were also included in some tests, representing cultivars of current interest or unknown resistance.

RESULTS AND DISCUSSION

Virulence

Table 4 shows the virulence frequencies in the eight sets of isolates tested in 2004. The eight populations obtained from air-borne spore samples were variable, in some cases differing from each other and from the leaf isolates. The low level of virulence for *Mla12* and to a lesser extent *Mlg*, *Ml(CP)*, *MlLa*, *Mlk1*, *Mla7* and *Mla1* at Stapleford could be due to the

Comment [JKM1]: V(Ab) higher at Stapleford than at Over

influence of a local population, perhaps from a cultivar with little resistance. However as the sample size was small this variation may not be significant. *Vra* was again detected in all the isolates tested, whilst *Vh* was present in over 90% of the populations. *Vg*, *V(CP)*, *VLa*, *Va12*, *Va7*, *V(Ab)* and *Va1* were all detected at high levels, although the frequency of *Va12* was much lower at Stapelford than at other locations. Although cultivars currently grown commercially carry *Mlg*, *Ml(CP)*, *Mla12* and *Ml(Ab*) resistance factors, there was little selection for *VLa*, *Va7* and *Va1* in 2004. *Va6* and *Va13* occurred at low levels in all samples; as few cultivars carry the corresponding resistance. *Vk1* and *Va9* were detected in most populations at low levels, despite the absence of selection. A few isolates carried *Va3*, for which there has to date been no selection. A spring barley cultivar thought to carry *Mla3* was however recommended for the first time for 2005.

Comment [JKM2]: I'm getting lost here – I thought the frequencies were unusually low at Stapleford…

Table 4. Virulence frequencies in single colony isolates of barley mildew from infected leaves (leaf sample) and from random samples of air-borne spores, and the area of barley cultivars with the corresponding resistance factors in 2004.

Virulence factor	Virulence frequency (%) *									Area of corresponding resistance
	Leaf sample	Random samples of air-borne spores								
		Suffolk	Ely, Cambs.	Cambridge	Over, Cambs.	Longstanton, Cambs.	Harston, Cambs.	Stapleford, Cambs.	Cherry Hinton, Cambridge	
Vh	99	100	98	100	97	91	97	95	95	29
Vra	100	100	100	100	100	100	100	100	100	38
Vg	98	100	98	85	87	85	91	79	98	26
V(CP)	67	100	93	83	87	85	88	79	98	26
Va6	16	8	13	10	16	12	6	16	10	<1
VLa	96	100	93	85	82	85	97	79	95	0
Va12	99	100	98	88	82	82	94	29	98	25
Vk1	32	27	18	15	16	27	28	11	25	0
Va7	96	92	90	90	87	88	84	84	85	<1
V(Ab)	95	96	90	90	76	82	84	79	90	19
Va1	78	96	83	75	84	77	81	68	78	<1
Va9	5	0	3	3	5	6	9	0	3	0
Va13	11	4	8	5	5	0	9	5	15	12
Va3	2	0	3	0	0	0	3	0	0	0
No. of isolates	138	26	40	40	38	34	32	40	40	

The frequency of virulences detected between 1994 and 2004 are shown in Table 5. Following a decline at the end of the 1990s, *Vh* has shown an increase in frequency during the last four years. This change reflects a fluctuation in the proporption of areas grown with cultivars carrying *Mlh*, which increased from 9% in 1999, to 30% in 2002 due to the popularity of winter cultivar Pearl. Virulence for *Mlra* was again detected in all isolates tested.

There was a slight decrease in the frequency of *Mlg* and *Ml(CP)*, to the lowest level reported for several years. *VLa*, *Vk1* and *Va9* also declined due to the decrease in selection for these virulences in the last few years. Less than 1% of the area planted since 1998 has carried *MlLa* or *Mla9* resistance factors, whilst no cultivars carrying *Mk1* have been grown since 1996. The occurrence of *Va7* and *V(Ab)* also decreased slightly in 2004, following a decline in popularity of Regina *(Mla7)* and Optic (*Mla12,Ml(Ab)*). Virulence for *Mla13* was similar to that in 2003, halting the decline observed over previous years. With the increase in the amount of area planted with Spire and Cocktail however (both carry *Mla13*) in 2004, it is

possible that the frequency of *Va13* may increase in the future. The frequencies of *Va1* and *Va12* remained similar to levels observed in 2003. Although a quarter of the barley area in 2004 carried *Mla12* there was only minimal selection for *Va1*. Fewer isolates than in 2003 carried *Va3*. However, only two isolates were derived from cultivars carrying *Mla3* in 2004, compared to nine in 2003.

Table 5. Virulence frequencies in barley mildew, 1994 to 2004.

Virulence factor	Virulence frequency (%) *										
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Vh	79	70	78	68	61	58	50	68	83	92	97
Vra	99	100	100	100	100	100	100	100	100	100	100
Vg	95	95	96	95	97	97	97	99	99	100	93
V(CP)	88	90	90	93	94	95	96	98	97	99	91
Va6	31	34	30	25	31	26	23	19	20	9	13
VLa	25	31	56	58	72	89	88	95	92	97	91
Va12	67	71	70	73	76	87	88	99	99	98	93
Vk1	72	72	76	71	73	66	61	57	52	35	25
Va7	69	73	76	73	76	85	95	99	96	96	90
V(Ab)	74	67	62	52	53	71	79	95	95	95	89
Va1	23	27	38	36	45	64	65	67	73	80	79
Va9	34	33	37	33	32	25	29	28	15	11	5
Va13	43	37	41	39	25	19	11	17	13	9	9
Va3	<1	<1	<1	1	1	1	5	1	2	5	1
No. of isolates	539	552	428	551	743	629	689	235	339	413	407

* Mean of leaf samples and random samples of air-borne spores for each year. Data from Slater & Clarkson (2004a).

Complexity of isolates

The number of virulence factors carried by isolates tested in 2004 is shown in Table 6. The Stapleford population included a large proportion of simple isolates; with 11% carrying only three virulence factors. Pathotypes with only two virulence factors were detected in the Cambridge, Cherry Hinton and Over populations. The remaining populations screened were similar, with the majority of pathotypes carrying nine virulence factors.

Table 6. Complexity of isolates taken from leaf samples and air-borne spores in 2004

No. of Virulence factors*	Relative number of isolates								
	Leaf samples	Random samples of air-borne spores							
		Suffolk	Ely, Cambs.	Cambridge	Over, Cambs.	Longstanton, Cambs.	Harston, Cambs.	Stapleford, Cambs.	Cherry Hinton, Cambridge
0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	0	0
2	0	0	0	5	3	0	0	0	3
3	1	0	1	3	11	6	3	11	0
4	1	0	0	3	0	0	0	5	0
5	0	0	0	3	0	9	3	5	0
6	0	0	0	3	0	3	0	0	0
7	3	0	8	3	3	0	3	0	5
8	7	4	8	5	5	12	9	16	13
9	54	73	65	65	63	59	63	53	58
10	27	19	15	8	16	12	19	11	20
11	6	1	3	5	0	0	0	0	0
12	1	0	0	0	0	0	0	0	3
13	0	0	0	0	0	0	0	0	0
Number of isols.	**138**	**26**	**40**	**40**	**38**	**34**	**32**	**19**	**40**

* includes all virulences listed in Table 2

Overall, the complexity of isolates, as shown in Table 7, was similar to 2003. 84% of the isolates tested carried nine or more virulence factors. While the trend for pathotypes to combine nine or more virulence factors continues, very few isolates carried more than ten factors.

Table 7. Comparison of the complexity of isolates collected from 1994 to 2004.

Number of virulence factors	% Frequency of isolates with each number of virulences*										
	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
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	0	<1	<1	0	0	0	0	0	0	0	1
3	0	<1	1	0	<1	0	0	0	0	0	3
4	1	1	1	1	1	1	1	0	0	0	<1
5	4	4	3	4	4	1	1	<1	<1	<1	1
6	10	11	7	11	10	8	6	0	1	1	<1
7	24	19	14	17	15	10	8	5	4	2	3
8	25	28	22	23	22	21	21	17	17	9	8
9	16	20	24	21	18	18	26	29	30	57	59
10	12	10	16	16	20	25	24	29	31	21	19
11	4	5	10	4	6	12	11	14	12	8	3
12	2	1	8	2	2	3	1	4	2	2	<1

13	0	0	3	<1	<1	1	0	0	2	0	0
Total no. of isolates	539	552	428	551	743	629	689	235	339	413	407

* includes all virulences listed in Table 2

Vh,Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1 was again the most common pathotype, detected in 54% of the isolates tested - a slight increase from levels reported in 2003. This pathotype consisting of nine virulence factors is capable of infecting all winter barleys on the 2005 Recommended List except Vanessa and Sequel, together with the most popular spring barley, Optic. The number of pathotypes detected, shown in Table 8, was lower than in 2003. There has been a continuing trend towards fewer pathotypes since 1996, with the dominant pathotype becoming more frequent.

Table 8. Number of pathotypes identified, 1995-2004.

	Total number of isolates tested	Number of pathotypes	Ratio of number of pathotypes to number of isolates tested	% frequency of most common 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
2004	407	67	0.16	54

Infection of barley cultivars

The majority of winter cultivars are potentially susceptible to over 90% of the mildew population. Virulence matching unknown specific resistance carried by Vanessa, Leonie and Clara (R'Van') occurred in 25% of isolates tested, while Kingston, Saffron and Sequel (all carrying *Mla6*) are at risk from only 13% of the population. However, if the area of cultivars carrying *Mla6* increases beyond its current low level it is likely that the incidence of pathotypes carrying *Va6* will increase; in the mid 1990s when Gleam and Sunrise were popular, a third of the population carried *Va6*. Amarena was resistant to all mildew isolates tested.

Although the specific resistance carried by most winter cultivars is matched by the bulk of the mildew population, many cultivars also carry good non-specific resistance. Haka and Flagon are potentially at risk from 97% of the population, yet with disease ratings of 8 have effective resistance in the field. Nevertheless, some cultivars currently grown have neither effective specific nor non-specific resistance e.g. Pastoral, with a rating of 2 it is susceptible to 100% of the population and lacks non-specific resistance.

Table 9. Proportion of mildew isolates tested in 2004 able to infect barley cultivars in 2004 HGCA Recommended List trials (Rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Antelope (7)	100	Kestrel (4)	91
Cannock (2)	100	Pearl (7)	91
Heligan (3)	100	Scylla (6)	91
Pastoral (2)	100	Aquarelle (6)	90
Pict (7)	100	Nocturne (4)	90
Colossus (5)	97	Regina (3)	90
Flagon (8)	97	Spectrum (6)	90
Haka (8)	97	Sumo (7)	87
Siberia (7)	97	Clara (7)	25
Jewel (6)	93	Leonie (8)	25
Rattle (8)	93	Vanessa (8)	25
Antonia (5)	93	Kingston (6)	13
Camion (5)	91	Saffron (5)	13
Carat (7)	91	Sequel (8)	13
Fanfare (6)	91	Amarena (9)	0

Spring cultivars	Proportion (%)	Spring cultivars	Proportion (%)
Optic (5)	89	Decanter (9)	0
Macaw (6)	61	Henley (9)	0
Kirsty (8)	23	Minstrel (9)	0
Rebecca (8)	20	Prestige (9)	0
Oxbridge	10	Riviera (9)	0
Spire (7)	9	Static (9)	0
Cocktail (8)	5	Toucan (9)	0
Doyen (8)	1	Troon (9)	0
Cellar (9)	0	Carafe (9)	?
Chalice (9)	0		

? = unknown resistance

Resistance factors in new cultivars

Additional cultivars carrying unknown resistance were included in differential tests. The number of isolates virulent on these cultivars in tests is shown in Table 10. The frequency of virulence for these cultivars varied greatly between sets of samples. Virulence for Tocado was detected in approximately half of the isolates derived from leaf samples and air spora at Stapleford, Cambridge and Cherry Hinton, but in only 15% of isolates from Ely, and was absent at Longstanton. Virulence for Macaw varied from 38% in Ely to 100% in Suffolk. Sumo virulence was also present in all of the Suffolk isolates, but in only 48% of the Ely population. How significant such differences are remains uncertain. Local populations may

be influenced by the cultivars grown nearby, but as in 2003 some sample sizes were small e.g. only 19 isolates were present in the Stapleford sample.

Table 10. Relative number of isolates virulent on additional cultivars included in differential tests in 2004

	Leaf isols	Air-borne spore samples							
		Suffolk	Ely, Cambs.	Cambridge	Over, Cambs.	Longstanton, Cambs.	Harston, Cambs.	Stapleford, Cambs.	Cherry Hinton, Cambridge
Vanessa	10	8	53	43	25	0	13	5	90
Kirsty	10	8	53	40	23	0	13	5	83
Rebecca	13	12	11	35	20	8	13	5	92
Oxbridge	11	8	10	30	10	0	13	5	87
Macaw	73	100	75	65	61	54	72	63	59
Tocado	54	42	43	45	34	0	38	58	50
Cocktail	7	4	10	0	5	0	6	0	10
Doyen	2	0	0	0	1	0	0	0	0
Sumo	97	100	95	85	87	88	94	79	95
Amarena	0	0	0	0	0	0	0	0	0
No. of isolates	138	26	40	40	38	34	32	19	40

Amarena, resistant to all isolates, carries specific resistance not matched by current UK populations. Virulence for Doyen, which is thought to carry *Mla3*, was present in 2% of the leaf isolates. The first commercial cultivars to carry *Mla3*, Doyen and Toby, entered Recommended list trials in 2003, but Toby was not recommended. As *Va3* is present in the population at a low level it is likely that the frequency will increase, should Doyen be grown widely. Only if Doyen possesses additional non-specific resistance will it retain its current rating of 8.

Virulence for Vanessa, Kirsty, Rebecca and Oxbridge also varied between sites. *V'Van*' was absent at Longstanton and infrequent at the remaining locations with the exception of Cherry Hinton, where it was detected in over 80% of the isolates tested. The abundance of isolates infecting Vanessa, Kirsty, Rebecca and Oxbridge at Cherry Hinton may be due to an area of one of these cultivars in the vicinity.

In 2003, the incidence of virulence for Vanessa, Kirsty and Rebecca was much lower in air-borne spore samples than in leaf samples. The data from 2004 tests shows a reversal of this trend, with more virulence for these cultivars present in leaf samples (Table 11). Some virulence frequencies have occasionally been higher in leaf samples when particular cultivars are targeted, resulting in a high number of samples from these cultivars. In 2003 14% of the leaf isolates tested were collected from cultivars which may carry *V'Van'*, while in 2004 only 6% of isolates were derived from infections on these cultivars.

Table 11. Relative virulence frequency for cultivars which may carry Vanessa resistance in 2003 and 2004.

	2003		2004	
	Leaf isols	Air spora isols	Leaf isols	Air spora isols
Vanessa (W)	24	4	10	31
Leonie (W)	24	4	-	-
Clara (W)	24	4	-	-
Kirsty (S)	20	4	10	28
Rebecca (S)	22	3	13	22
Oxbridge (S)	-	-	11	9
No. of isols.	207	204	138	269

(W) = Winter (S) = Spring

It seems likely that Vanessa, Leonie, Clara, Kirsty, Rebecca and Oxbridge carry resistance factors in common, although Kirsty, Rebecca and Oxbridge may have additional resistance. Whether this additional resistance is similar is not known.

No new resistance groups were identified in 2004, although Amarena carries an unknown specific resistance.

Currently there is little diversification potential in spring barley. Cultivars either carry *mlo* (the majority of cultivars), *Mla12,Ml(Ab)* (Optic), *Mla13* (Spire, Cocktail) or the uncharacterised resistance in Kirsty and Rebecca. With the recommendation of Doyen however, the first *Mla3* cultivar to be listed, an additional diversification group is generated.

The Resistance genes of HGCA Recommended List barley cultivars (2005) are shown in Table 12.

Table 12. Resistance genes of barley cultivars (2005 HGCA Recommended List cultivars in **bold**).

0	*Mlh,Mlra(Mla6,Mlv?)*	*mlo*
Antelope (W)	Kingston **(**W)	**Cellar** (S)
		Chalice (S)
Mlra	*Mla12*	**Decanter** (S)
Cannock (W)	**Jewel** (W)	Henley (S)
Heligan (W)		Minstrel (S)
Pict (W)	*Mlra,Mlg,Mla12*	NFC Tipple (S)
Pastoral (W)	**Carat** (W)	**Prestige** (S)
		Power (S)
Mlh,Mlra	*Mlh,Mlra,Mlg,Mla12*	**Riviera** (S)
Colossus (W)*	Rattle (W)	**Static** (S)
Flagon (W)		**Troon** (S)
Haka (W)	*Mla7 (Mlra?)*	Toucan (S)
Siberia (W)	**Aquarelle** (W)*	Waggon (S)
	Nocturne (W)	Westminster (S)
Mlh, Mlg	**Regina** (W)	
Antonia (W)		*Mla3*
	Mlh,Mla7	**Doyen (S)**
Mlra,Mlg,Ml(CP)	Spectrum (W)	
Fanfare (W)		*'Van'*
	Mlh,Mlra,Mla7	Clara (W)
Mlh,Mlra,Mlg,Ml(CP)	Vertige (W)	Leonie (W)
Camion (W)*		**Vanessa** (W)
Kestrel (W)	*Mla12,Ml(Ab)*	
Pearl (W)	**Optic** (S)	Unknown
Scylla (W)	Wicket (S)	Amarena (W)
		Carafe (S)*
Mlh,Mla6	*Mla1+?*	**Kirsty (S)**
Tallica (W)	Macaw (S)	Oxbridge (S)
		Rebecca (S)*
Mlra,Mla6	*Mla13*	**Sumo** (W)
Sequel (W)	**Spire** (S)	Tocado (S)
Mlh,Mlg,Ml(CP),Mla6 (Mlra?)	*Mla13+?*	
Saffron (W)	**Cocktail** (S)	

* newly recommended for 2005 (W) winter cultivar (S) spring cultivar

Virulence for *mlo* cultivars

Fewer isolates produced infection on Apex and Riviera cultivars (*mlo* differentials)~~,~~ in 2004 tests than in previous years (Table 13). The area of *mlo* cultivars grown has not changed substantially over this period, fluctuating around 20% of the total barley area. Further tests with 2003 isolates confirmed previous results which had indicated that the level of partial virulence for *mlo* has not increased over the last few years, despite the continued detection of partially virulent pathotypes (Slater & Clarkson 2004b).

Table 13. Proportion of isolates infecting Apex and Riviera in differential tests, 1996-2004 (as percentage of isolates tested) and area sown with *mlo* carrying cultivars.

Year	Apex	Riviera	Area of mlo cultivars *
1996	29	15	20
1997	24	13	17
1998	29	24	16
1999	27	23	20
2000	44	32	17
2001	48	34	22
2002	30	13	19
2003	43	27	23
2004	21	12	17

* percentage of total barley area

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MILDEW OF OATS

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INTRODUCTION

Mildew levels were generally high on susceptible cvs by late winter and remained so throughout the year.

SEEDLING TESTS WITH 2004 ISOLATES

Methods

Samples were received from 30 winter and 25 spring oat cvs (Table1). They were collected at sites inCambridge(18), Northumberland(14), Co.Down(16) and Aberdeen(7). Isolates of *Blumeria graminis* DC Speer f.sp.*avenae* were cultured from 20 samples and were inoculated onto seedlings of the differential cvs (Table 2). 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 1 Source cultivars of 2004 oat mildew samples

Cv. [1-9 rating]	No. of samples	Cv. [1-9 rating]	No. of samples	Cv. [1-9 rating]	No. of samples
Winter oat				**Spring oat**	
Jalna [6]	5	Ayr [6]	2	Winston [8]	5
Buffalo [2]	5	Mascani [7]	2	Emotion [6]	5
Expression [6]	2	Grafton [5]	2	Drummer[6]	5
SW Dalguise [4]	2	Gerald [5]	2	Banquo[7]	4
SW Kinross [6]	2	Hendon [6]	2	Firth [8]	4
Millennium [5]	2	94-116Cn4/1	2	SW Argyle[6]	2

Table 2 Differential cultivars used for isolate testing

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

Results

Based on the reactions of the differential cvs, 15 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. The other isolates additionally carried OMV-4, which overcomes the *A. barbata* resistance in the translocation line Cc6490 (OMR-4). These race 7 isolates were cultured from samples collected at trial sites at NIAB, Cambridge(3) and Cockle Park, Northumberland(2). The frequency of pathotypes carrying OMV-4 has fluctuated between years since it was first identified in 1980. It has shown a mean frequency of about 12% during this period although the matching resistance (OMR-4) has not been deployed in any Recommended List cvs. It may however be in some advanced breeding lines. Previous years tests have identified all the currently recommended winter and spring oat cvs to be seedling susceptible to race 5 isolates but there does appear appear to be good levels of adult plant resistance particulary in spring oats as indicated by their disease ratings on the HGCA Recommended Lists of Winter and Spring Oats.

YELLOW RUST OF WHEAT

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SUMMARY

Virulence for Robigus (WYR CV+) was identified in 31% of the isolates tested in 2004. All of these carried the virulence combination WYV9,17,CV.
Virulence for Cordiale (WYR 7) was detected at a very low frequency in isolates collected in 2004 and also in adult plant tests of isolates collected in 2002 and 2003.
Combined virulence for Robigus and for cultivars carrying WYR6,9,17 (e.g. Napier, Access) has still not been confirmed.
Nearly 50% of the UK wheat acreage in 2004 was occupied by resistant cultivars for which no corresponding virulence has been detected.

INTRODUCTION

The incidence of yellow rust in wheat crops and variety trials was extremely low in 2004.

SEEDLING VIRULENCE TESTS OF ISOLATES COLLECTED IN 2004

Methods

48 samples of wheat yellow rust were collected between April and June from 33 different cultivars (Table 1). All came from naturally infected trials in the Cambridge area. These were successfully cultured and tested.

Virulence tests were carried out on seedlings of the differential cultivars listed in Table 2, 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. Isolates tested in 2004

Source cv	WYR	No. isolates	Source cv	WYR	No. isolates
Glasgow	0?	1	Talon	CV	1
Victo	0	1	Hereward	CV+	2
Vuka	0	7	Dickson	CV+	1
Soissons	?3	1	Oxbow	CV+	2
Einstein	?6+	1	Robigus	CV+	4
Longbow	1,2,6	1	Senator	CV+	1
Clement	9	1	Wizard	CV+	1
Tanker	9	1	Ashby	R	1
Stetson	1,9	1	Richmond	R	1
Hornet	6,9	2	Nijinsky	x, APR	1
Reaper	17	1	Ambrosia	?	1
Brigadier	9,17	2	Defender	?	1
Savannah	9,17	1	Hybred	?	1
Bentley	6,17	2	Hyno Esta	?	1
Steadfast	6,17	1			
Welford	6,17	2			
Access	6,9,17	1			
Madrigal	6,9,17	1			
Napier	6,9,17	1	TOTAL		48

Table 2. Differential cultivars used in 2004 wheat seedling virulence tests.

Differential cultivar	WYR factor	Gene designation
Core set		
Chinese 166	WYR 1	*Yr1*
Kalysona	WYR 2	*Yr2*
Vilmorin 23	WYR 3	*Yr3+*
Nord Desprez	WYR 3	*Yr3+*
Hybrid 46	WYR 4	*Yr4*
Heines Kolben	WYR 2,6	*Yr2, Yr6*
Heines Peko	WYR 2,6	*Yr2, Yr6*
Lee	WYR 7	*Yr7*
Reichersberg 42	WYR 7	*Yr7*
Compair	WYR 8	*Yr8*
Kavkaz x 4 Fed	WYR 9	*Yr9*
Clement	WYR 9	*Yr9*
Moro	WYR 10	*Yr10*
Yr 15/6*AvS	WYR 15	*Yr15*
VPM 1	WYR 17	*Yr17*
Rendezvous	WYR 17	*Yr17*
Carstens V	WYR CV	*Yr32*
Spaldings Prolific	WYR Sp	*Yr Spaldings Prolific*
Additional CVs		
Cordiale	WYR 7	
Talon	WYR CV	
Robigus	WYR CV+	
Oxbow	WYR CV+	
Cadenza	R	
Option	R	
Solstice	R?	
Xi19	R	
Buster	R	

R = resistant to all isolates

Results

Virulence frequencies for 2004 are shown in Table 3, together with results from 1990 – 2003 (Bayles *et al*, 2003). These data should be interpreted with caution because of the non-random nature of the sampling and the small number of isolates tested in some years.

Virulences WYV1, WYV2, WYV3, WYV9 and WYV17 continued to be detected at very high levels, being present in 85-100% of isolates tested in 2004. The frequencies of WYV4, WYV6 and WYV32 were intermediate (38-50%). The frequency of WYV7

returned to a low level after an increase in 2003. Virulence for the cultivars Oxbow and Robigus was detected in 31% of isolates.

As in previous years, no virulence was detected for WYR8, WYR10, WYR15 or for the cultivars Buster, Cadenza, Option or Xi19. No isolates were virulent on Solstice, despite indications of low levels of virulence in 2002 and 2003.

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Table 3. Virulence frequencies: 1990 to 2004.

Virulence for:	**90**	**91**	**92**	**93**	**94**	**95**	**96**	**97**	**98**	**99**	**00**	**01**	**02**	**03**	**04**
WYR 1	85	91	88	89	65	90	97	100	99	99	100	100	97	100	100
WYR 2	100	100	100	98	100	99	97	100	99	99	100	100	97	100	100
WYR 3	100	100	100	100	100	100	100	100	100	100	100	100	97	100	93
WYR 4	91	86	86	89	86	67	59	47	79	87	90	74	63	86	50
WYR 6	69	64	88	68	41	35	16	1	7	21	32	39	31	50	42
WYR 7	9	19	7	8	4	0	3	7	4	10	4	0	3	36	4
WYR 8		0	0	0	0	0	0	0	0	0	0	0	0	0	0
WYR 9	94	88	76	84	94	95	97	99	99	99	92	90	88	93	100
WYR 10												0	0	0	0
WYR 15												0	0	0	0
WYR 17						57	84	99	99	100	96	77	88	93	85
WYR CV					75	55	9	13	1	4	16	42	73	64	38
WYR A									84	91	88	90	97	-	-
WYR So									78	91	90	77	67	93	-
WYR Sd									100	98	100	84	81	100	-
WYR Sp									0	0	0	0	0	7	0
Additional cvs															
Robigus	CV+														31
Oxbow	CV+										16	32	50	50	31
Buster	R			3	0	0	0	0	0	0	0	0	0	7	0
Cadenza	R											0	0	0	0
Option	R												0	0	0
Solstice	R?												6	7	0
Xi19	R												0	0	0
No. of isolates tested	**67**	**42**	**77**	**63**	**49**	**83**	**32**	**138**	**94**	**97**	**50**	**31**	**36**	**14**	**48**

Table 4 shows the frequencies of the 21 pathotypes identified over the 3-year period 2002 - 2004. Two groups of pathotypes were predominant. These were (1) pathotypes carrying the WYV6,9,17 combination (virulent on cultivars such as Madrigal, Napier and Access) and (2) pathotypes carrying the WYV9,17,CV combination (virulent on cultivars such as Oxbow, Consort and Robigus). Isolates in these two groups accounted for 72% of those tested in 2004. A few isolates combining the virulence of (1) and (2) have been tentatively identified in differential tests, but this combination has never yet been confirmed in more extensive tests on the relevant cultivars.

A number of other, usually less complex, pathotypes were detected at low frequencies. These included the original 'Brigadier-virulent' types, carrying the WYV9,17 virulence combination without WYV6, which dominated the population in the mid 1990s.

Table 4. Frequency (%) of pathotypes detected in 2004, 2003 and 2002.

Pathotype (WYV)*	2002	2003	2004
1,2,3,4,**6,9,17**	6	29	23
1,2,3,**6,9,17**	6	7	13
1,2,3,4,**6**,7,**9,17**	3	0	0
1,2,3,4,**9,17,CV**	31	14	19
1,2,3,4,7,**9,17,CV**	0	21	2
1,2,3,**9,17,CV**	11	7	15
1,2,3,4,**6,9,17,CV**	6	7	2
1,2,3,4,**6**,7,**9,17,CV**	0	7	0
1,2,3,**6**,**9,17,CV**	6	0	0
1,2,3,**9,17**	6	0	6
1,2,3,4,**9,17**	0	0	4
1,2,3,7,**9,17**	0	0	2
1,2,3,9	0	0	8
1,2,9	0	0	2
1,2,6,9	0	0	4
3	3	0	0
1,2,3	3	0	0
1,2,CV	3	0	0
1,2,3,4	3	0	0
1,2,3,4,17	3	0	0
1,2,3,4,7,CV	0	7	0

* excludes variation in virulence for WYRSo, WYRSd and WYRSp

Table 5 shows the percentage of isolates tested in 2004 that were potentially virulent on each of the cultivars making up the UK wheat acreage in that season. Virulence was common (greater than 30%) for cultivars occupying nearly 50% of the acreage and absent for cultivars occupying most of the remainder. The exception was virulence for the cultivar Cordiale (WYR 7), at a very low frequency of 4%. Previous experience suggests that if the acreage of this cultivar were to increase significantly from its current low level (0.5%), the frequency of corresponding virulence would be likely to increase rapidly.

Table 5. % 2004 isolates virulent on main UK cultivars grown during the same season

Cultivar	WYR factors	1-9 resistance rating*	% Area grown#	% isolates virulent
Claire	x, APR	9	18.6	0
Consort	CV+	5	16.4	31
Solstice	R	9	6.9	0
Malacca	x, APR	9	6.8	0
Einstein	?6+	5	6.2	42
Robigus	CV+	3	5.9	31
Hereward	CV+	5	4.9	38
Deben	x, APR	9	4.9	0
Napier	6,9,17	4	4.4	38
Access	6,9,17	4	3.1	38
Xi 19	R?	9	2.7	0
Tanker	9	5	2.6	100
Soissons	3	6	2.4	93
Richmond	R	7	2.2	0
Savannah	9,17	4	1.8	86
Option	R	9	1.8	0
Nijinsky	R	9	1.3	0
Riband	13	6	1.3	?
Exsept	R	9	0.7	0
Wizard	CV+	4	0.6	31
Charger	x, APR	7	0.6	0
Gladiator	x,APR	9	0.6	0
Cordiale	7	(3/4)	0.5	4

*HGCA Recommended List for 2004/05, or most recent where cultivar is no longer in trials
Seedstats Journal – NIAB (courtesy of DEFRA, SASSA, SERAD and DARD)

ADULT PLANT TESTS

Methods

10 isolates (Table 6) were tested on a set of 52 cultivars in adult plant tests in field isolation nurseries. Isolates comprised seven from the 2003 survey, undergoing adult plant testing for the first time and three from the 2002 survey, included for confirmation of previous adult plant test results (Annual Report for 2003). Seedling tests of the same isolates and cultivars were carried out under controlled environment conditions.

Table 6. Isolates tested on adult plants in 2004.

Isolate number	Source		Virulence in previous seedling tests on differential cultivars
	Location	Cultivar	
02/16/10	Cambs	Buchan	1,2,3,6,7,9,17,CV
02/70	Morley	Robigus	1,2,3,9,CV
02/84	Cambs	Imp	3,4,CV
03/1	Cambs	Robigus	1,2,3,4,7,9,17,CV
03/7	Lincs	Brock	1,2,3,4,7,(CV)
03/18	Cambs	Soissons	1,2,3,4,7,9,17,CV
03/22	Cambs	Access	1,2,3,4,6,9,17,CV
03/505	Cambs	Goodwood	1,2,3,4,6,(7),9,17,CV
03/514	Cambs	Charger	3,4,17,CV
03/515	Cambs	Goodwood	1,2,3,4,6,7,9,17,CV

Results

Results of adult plant tests are shown in Table 7. Shading has been used to highlight increased levels of infection indicative of compatible cultivar x isolate interactions. Cultivars have been grouped in the table for purposes of discussion only.

Cultivars in Group A maintained their previous high levels of adult plant resistance when exposed to isolates collected in 2003.

Isolates 03/7, 02/16/10 and 03/18 gave increased infection on Brock (WYR7,14) and on Cordiale (also believed to carry WYR7).

Isolate 03/1 appeared to carry a limited number of virulence factors, but did give a high level of infection on the adult plant resistance WYR13 (in M. Huntsman).

Isolates 03/22, 03/505 and 03/515 were virulent on Group B cultivars (WYR6,(9),17). 03/515, had been flagged up in seedling virulence tests as possibly carrying combined virulence for Group B cultivars and Group C1/C2 cultivars (WYRCV+). Adult plant results confirmed virulence for Group B and for Group C1 (Talon and Hereward), but not for Group C2 (Oxbow, Consort, Robigus etc.).

Isolates 03/514 and 02/84 were relatively simple pathotypes, both lacking WYV1 and WYV2, but carrying WYV CV. These were virulent on Group C1, but not Group C2, cultivars. Interestingly, these isolates gave only very low levels of infection on Glasgow, a cultivar which is highly susceptible to most isolates and is generally regarded as having no effective specific resistance factors.

Isolate 02/70 was virulent on all Group C cultivars, confirming 2003 results. Seedling tests indicated that infection on Group B cultivars and on Cordiale and Brock was probably due to contamination from adjacent nurseries after inoculation. Earlier

indications that 02/70 might possess increased virulence for Xi19 and Scorpion 25 were not confirmed.

CONCLUSIONS

Virulence for the cultivars Oxbow and Robigus, which carry specific resistance derived from Carstens V together with unidentified specific resistance, is now common and was detected in nearly one third of isolates from the 2004 survey. Robigus is increasing in popularity and it is predicted that it will occupy around 20% of the UK wheat acreage for harvest 2005. Given its susceptibility, there is a clear risk of epidemic development in this and other Recommended cultivars with the same or similar resistances.

It appears that pathotypes combining virulence for Robigus (WYR CV+) with virulence for cultivars such as Napier and Access (WYR 6,9,17) have failed to evolve so far. The two corresponding groups of pathotype WYV9,17,CV+ and WYV6,9,17 have remained distinct, with the benefit that diversification between two groups of popular cultivars can still be an effective strategy for reducing the spread of yellow rust on the farm.

Virulence for WYR7 has been detected at a low level in the population since its first detection in 1971. Until the recommendation of Cordiale in 2004, the most recent commercial cultivar to carry the WYR7 resistance was Brock, in the late 1980s. The likelihood is that if Cordiale were to become widely grown, the corresponding virulence would increase rapidly, exposing its susceptibility.

On the positive side, nearly 50% of the UK wheat acreage was occupied in 2004 by cultivars with high levels of adult plant resistance, effective against the current yellow rust population. It is important that this proportion is not eroded.

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

Isolate No.		**03/7**	**02/16/10**	**03/18**	**03/1**	**03/22**	**03/505**	**03/515**	**03/514**	**02/84**	**02/70**
Virulence Expected* ***Actual*** **		1,2,3,4,7,(CV) ***1,2,3,4,7***	1,2,3,6,7,9,17,CV ***1,2,3,4,7,(CV)***	1,2,3,4,7,9,17,CV ***1,2,3,4,7,(17)***	1,2,3,4,7,9,17,CV ***1,2,3***	1,2,3,4,6,9,17,CV ***1,2,3,4,6,9,17***	1,2,3,4,6,(7),9,17,CV ***1,2,3,4,6,9,17***	1,2,3,4,6,7,9,17,CV ***1,2,3,4,(6),(9),17,CV***	3,4,17,CV ***3,4,17,CV***	3,4,CV ***3,4,17,CV***	1,2,3,9,CV ***1,2,3,4,(9),(17),(CV)***
Cultivar	**WYR**										
Group A											
Claire	x,APR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malacca	x,APR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Option	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Richmond	R	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.3
Smuggler	x,APR	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.1	0.0
Nijinsky	x,APR	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.3
Deben	x,APR	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.1
Istabraq	x,APR	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	*	0.8
Gladiator	x,APR	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.2
Exeter	x,APR	0.0	0.5	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Apostle	2,6,APR	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.1	0.2
Solstice	R	0.0	0.0	0.0	0.3	0.1	0.8	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
Group B											
Napier	6,9,17	1.0	6.3	4.3	1.0	21.3	16.8	15.5	0.0	2.1	*12.3*
Access	6,9,17	0.0	9.8	3.6	0.0	18.8	18.8	14.5	3.0	6.0	*8.1*
Bentley	6,17	0.0	1.5	4.0	0.0	13.8	4.3	5.3	2.0	1.8	*8.0*
Steadfast	6,17	0.0	1.3	0.2	0.0	11.8	8.3	1.8	0.0	0.8	*4.9*
Welford	6,17	0.8	0.0	0.3	0.0	10.0	6.5	2.9	0.0	0.0	*2.4*
Ambrosia	6,17	0.0	2.5	0.0	0.0	14.5	10.3	11.3	0.3	0.0	*5.5*
Brompton	6,17	0.0	0.0	0.0	0.0	1.6	1.3	1.8	0.0	0.2	*0.3*
GroupC1											
Talon	CV	1.5	3.3	10.8	3.8	0.2	0.0	14.3	15.0	19.3	9.0
Hereward	CV+	0.0	0.0	2.9	0.0	0.0	0.0	9.8	14.3	6.5	6.8
Group C2											
Oxbow	9,CV+	0.0	0.0	9.5	5.5	5.3	0.0	0.3	0.3	5.3	18.5
Consort	CV+	0.0	0.0	2.2	2.3	0.0	0.0	0.0	0.0	0.0	4.5
Robigus	CV+	0.0	0.8	7.8	2.8	3.0	0.0	0.0	0.3	2.5	15.0
Wizard	CV+	0.0	0.3	2.8	4.8	0.4	0.0	0.0	0.0	0.1	7.8
Dickson	CV+	0.3	0.0	5.6	1.3	1.0	0.0	0.0	1.3	0.0	9.8
Senator	9,CV+	0.0	1.0	8.5	7.5	3.8	1.8	0.9	0.0	0.4	8.3
Dart	CV+	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	2.8

* = from previous seedling virulence tests on differential cultivars (Table 5)

** = from 2004 seedling tests on cultivars included in adult plant tests (Table 6) plus differential cultivars

Infection levels shown in italics indicate suspected contamination from adjacent nurseries

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

Isolate No.		**03/7**	**02/16/10**	**03/18**	**03/1**	**03/22**	**03/505**	**03/515**	**03/514**	**02/84**	**02/70**
Virulence Expected* ***Actual****		1,2,3,4,7,(CV) ***1,2,3,4,7***	1,2,3,6,7,9,17,CV ***1,2,3,4,7,(CV)***	1,2,3,4,7,9,17,CV ***1,2,3,4,7,(17)***	1,2,3,4,7,9,17,CV ***1,2,3***	1,2,3,4,6,9,17,CV ***1,2,3,4,6,9,17***	1,2,3,4,6,(7),9,17,CV ***1,2,3,4,6,9,17***	1,2,3,4,6,7,9,17,CV ***1,2,3,4,(6),(9),17,CV***	3,4,17,CV ***3,4,17,CV***	3,4,CV ***3,4,17,CV***	1,2,3,9,CV ***1,2,3,4,(9),(17),(CV)***
Cultivar	**WYR**										
Others											
Scorpion 25	?	0.0	0.0	0.0	0.0	1.5	0.3	3.6	0.8	0.2	0.1
Xi19	?	0.0	0.0	0.0	0.0	1.9	0.0	3.1	0.8	1.5	0.3
Einstein	?6	0.0	0.8	0.2	0.0	9.3	4.0	13.3	5.3	11.5	3.3
Defender	?9,17	0.0	0.8	0.3	0.0	6.0	1.5	0.3	0.0	0.3	0.2
Atlanta	x,APR	0.0	0.8	0.0	0.0	2.0	0.3	0.1	0.0	0.0	0.5
Glasgow	?1 2	10.5	10.3	11.0	3.8	11.0	5.8	7.3	1.3	1.5	8.0
Cordiale	7	11.0	13.0	12.0	0.0	0.4	0.0	0.0	0.0	5.8	*9.3*
Brock	7,14	14.3	15.5	14.3	1.3	1.4	0.0	0.0	0.8	2.3	*12.5*
M. Huntsman	13	0.0	0.5	11.8	10.0	6.0	1.8	1.8	0.5	0.4	9.0
Hobbit	14	10.8	11.0	14.3	4.5	15.0	16.0	13.3	12.3	11.8	8.0

* = from previous seedling virulence tests on differential cultivars (Table 5)

** = from 2004 seedling tests on cultivars included in adult plant tests (Table 6) plus differential cultivars

Infection levels shown in italics indicate suspected contamination from adjacent nurseries

YELLOW RUST OF BARLEY

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Yellow rust of barley was rare in 2004 and only three isolates were tested. These all carried BYV1, but lacked BYV2 and BYV3.

INTRODUCTION

Yellow rust of barley was extremely rare in 2004 and only three samples were received, all from the Lothian region of Scotland.

METHODS

The three samples received were successfully cultured and tested.

The cultivars from which samples were collected are shown in Table 1. These were susceptible winter barley cultivars with resistance ratings of 4 or below.

Table 1. Cultivars from which samples of barley yellow rust were collected in 2003.

Source cultivar	Resistance rating (1-9)*	% Area grown#	No. isolates tested
Amarena (w)	4	0.1	1
Regina (w)	2	0.8	1
Siberia (w)	4	1.8	1
TOTAL			**3**

(w) = winter cultivar
* source: HGCA Recommended List for 2005/6
# source: NIAB seed production statistics for England and Wales for 2004.

Table 2 lists the standard differential cultivars and additional cultivars that were used in the 2004 seedling virulence tests.

Table 2. Differential cultivars used to test isolates of barley yellow rust in 2004.

Cultivar	BYR factor
Astrix	BYR 1
Atem	BYR 1
Bigo	BYR 2
Varunda	BYR 2
Mazurka	BYR 2
Triumph	BYR 3
Additional cultivars	
Gleam	Rx
Pearl	Rx
Fanfare	Rx
Manitou	Rx
Optic	Rx
Derkado	R

R = resistant to all isolates
Rx = interacts with isolates, but specific resistance not identifiable as BYR1, BYR2 or BYR3

Results

Table 3 shows virulence frequencies for 1984-2004 (no samples were received in 1996, 1997 or 1998). These figures should be viewed with caution due to the extremely low incidence of the disease and small number of samples tested.

All isolates tested in 2004 were characterised as BYV 1 and were also virulent on Gleam and Manitou. One of the three was also virulent on Pearl. Unlike previous years, no isolates were virulent on Fanfare or Optic. Once again, no virulence was detected for the spring cultivar Derkado.

Table 3. Percentage frequency of barley yellow rust virulence factors for 1984 – 2004.

	’84	’87	’89	’90	’91	’92	’93	’94	’95	’99	’00	’01	’02	‘03	'04
BYV1	100	100	100	100	100	100	100	100	100	100	86	100	100	92	100
BYV2	100	100	100	0	100	100	100	100	100	100	71	0	0	23	0
BYV3	86	22	75	0	0	0	0	100	0	100	71	0	50	38	0
Gleam	Rx												38	100	100
Pearl	Rx												33	15	33
Fanfare	Rx												38	77	0
Manitou	Rx												50	15	100
Optic	Rx												13	31	0
Derkado	R												0	0	0
No. of Isolates tested	7	9	4	1	1	2	1	1	3	1	7	3	8	13	3

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BROWN RUST OF WHEAT

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Brown rust was again at very low levels in 2004. Several of the current HGCA Recommended List winter and spring wheats have high (resistant) disease ratings and are estimated to have occupied around 38% of the total wheat hectarage in 2004. Only two samples were received but differences in host:pathogen reactions between isolates indicated that WBR-1(Lr26) was carried by cvs Brompton, Fastnet, Kipling, Asagai, Gatsby, Ambrosia and Director. Increased virulence to cv. Claire, identified in one isolate in 2003, was not confirmed in the field; this may however have been due to contamination of the nursery. Cvs Steadfast and Welford are postulated as carrying genes Lr10, Lr26 and Lr37 based on the association of these genes with stripe rust resistance (WYR) factors. The widely deployed temperature-sensitive, adult plant resistance conferred by Lr37 remains effective in the field.

INTRODUCTION

Brown rust was, as in the previous two years, found only at trace levels in the commercial, winter crop (Crop Monitor Winter Wheat Survey, 2004). Nearly 40% of winter wheat cvs on the current HGCA Recommended List have disease ratings of 8 or 9 (highly resistant) and in 2004 were estimated to have occupied around 35% of the area sown to winter wheat (NIAB 2004). It is estimated however, that about 25% of the winter wheat area was sown to recommended cvs with disease ratings of 3, 4 and 5 (susceptible) and from this it might be expected that overall disease levels would be higher.

The majority of the current recommended spring wheats are highly resistant and are estimated to have occupied around 86% of the hectarage sown to the crop in 2004. However spring wheats occupy only around 5% of the total area sown to wheat.

SEEDLING TESTS WITH YEAR 2004 ISOLATES

Methods

Isolates of *Puccinia triticina* were cultured from the 2 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) potential new wheat cvs (Table 3).

Table 1 * Standard WBR cvs used in tests with 2004 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 wheat cvs included in tests with isolates from the 2004 survey

Brompton	Dover	Piranha
Fastnet	Alchemy	Hurley
Kipling	Hyperion	Zebedee
Asagai	Gatsby	Mascot
Defender	Director	Ambrosia

Plants were grown until 14 days old 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°C and 12 h photoperiod) or a high temperature regime (25°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

Isolate WBRS-04-01 (ex cv. Victo) was identified as carrying virulence factors WBV-1 and WBV-7. Isolates identified as carrying WBV-1,7 have remained at a very low frequency although the individual virulences have been identified in 85% (WBV-1) and 73% (WBV-7) of the isolates tested since the year 2000 (Jones,2004). They are however often combined with WBV-2 and this virulence combination, WBV-1,2,7, has been dominant in recent years. Isolate WBRS-04-02 (ex cv. Istabraq) failed to infect any of the standard WBR differential cvs at both temperature regimes. It lacked virulence to cvs Fundin (WBR-2) and Sterna (WBR-7) at 25°C and was avirulent on the other differential cvs at 10°C and 25°C. The frequency of this pathotype, designated WBV-0, has remained fairly stable with a mean of about 20% over the last decade.
The two isolates were also differentiated by the Thatcher lines Lr3 and Lr26 which are the resistance genes carried by the differential cvs Sterna and Clement respectively. The isolates induced a similar pattern of responses on the other Lr lines. Lines Lr1, 2a, 2b, 2c, 9, 19, 21, 24 and 28 were resistant at both temperatures, whilst Lr15 and 17 were susceptible. Resistance conferred by Lr11 was effective at 10°C and that of Lr 23 at 25°C.
Of the newly recommended and potential new cvs several responded similarly to the isolates as cvs Clement (WBR1) and Sterna (WBR7) but their reaction types were very like those expressed by cv. Clement and they are therefore postulated to carry WBR-1(Lr26). These cvs include Brompton, Fastnet, Kipling, Asagai, Gatsby, Ambrosia and Director. Cultivars Mascot, Piranah and Defender were susceptible to both isolates although the reaction types of the latter two were mixed at 25°C. Cv. Hurley was resistant to the isolates at both temperature regimes. The remaining cvs, Dover, Alchemy, Hyperion and Zebedee gave very mixed reactions at low and high temperatures making classification as susceptible or resistant difficult.

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 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 and cv. Thatcher (susceptible check). Two replicates of each cv. were inoculated with one each of the isolates WBRS-04-01 (WBV-1,7) and WBRS-04-02 (WBV-0).
Post-inoculation plants were incubated at low (10°C) or high (25°C) temperatures as described previously (Jones and Clifford, 1997).

Results (Table 4)

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).

Group 1: The overall resistances of the spring wheat cv. Tybalt and the winter wheat cvs Robigus and Glasgow were effective at both temperatures.

Group 2: The temperature-sensitive resistances of all these spring cvs was effective at 10^{o}C. Previous years tests have shown resistance in cv. Belvoir to be of the overall type being effective in seedling and adult plants, whilst that in cv. Paragon is only effective at the later growth stages. Compared to these cvs, at 25 ^{o}C cv. Morph showed much less disease.

Group 3: The adult plant responses of several cvs were very mixed making classification as susceptible or resistant difficult. Nevertheless, the cvs appeared to display a mainly resistant infection type with the exception of cvs Richmond and Ashby which showed a more susceptible response at 25^{o}C to isolate WBRS-04-01. The resistances of all cvs within the group, except for cv.Exeter, appear to be somewhat temperature-sensitive as they were less heavily infected at 10^{o}C. Cv. Exeter, whose resistance is expressed at later growth stages, was infected at similar levels at low and high temperatures. In previous years using different WBR isolates, cv. : isolate interactions have shown cv Wizard to have adult plant resistance and the spring cv. Ashby to have overall resistance.

Group 4: These cvs were resistant to WBRS-04-02 (WBV-0) but were generally moderately to heavily infected by isolate WBRS-04-01 (WBV-1,7). Three of the cvs, Gladiator, Napier and Savannah, are postulated, on the basis of previous tests, to carry the matching resistance factor WBR-1 (Lr26). However they were not susceptible to WBRS-04-01 but expressed a mixed, mainly resistant reaction to this isolate at one or other of the test temperatures. This resistance is presumably conferred by the additional resistance(s) they are postulated to carry. In cvs Napier and Savannah resistance was conferred by Lr37, a temperature-sensitive resistance known to be more effective at low temperatures. Cv Gladiator carries additional, unknown, adult plant resistance effective against WBV-1 pathotypes. Cv. Claire does not carry WBR-1(Lr26) but responded similarly to cv. Savannah showing temperature-sensitive, adult plant resistance that was more effective at 10^{o}C. It has proved susceptible to some isolates in previous controlled environment tests but its resistance remains effective in the field. .

Group 5: The temperature-sensitive resistances of cvs Defender and Atlanta were effective against both isolates at 25^{o}C but ineffective at low temperature. However in 2003 seedling tests this resistance was only expressed against a small percentage of the isolates tested.

Group 6: Cv. Cordiale was susceptible to isolate WBRS-04-01 but resistant to WBRS-04-02 which lacks virulence to any of the standard WBR differential cvs. It was seedling susceptible to all the 2003 isolates and it has a low (susceptible) disease rating of 4. It appears from these adult plant tests that it may carry adult plant resistance effective against this ‘simple’ pathotype.

Group 7: This group comprises cv. Thatcher (susceptible check) and the Thatcher near isogenic lines with single genes for resistance thought to be the most commonly deployed in UK cvs. Line Lr26 was susceptible to isolate WBRS-04-01 which carries the matching virulence, (WBV-1), but resistant to WBRS-04-02. Lines Lr10, Lr13 and Lr37 were also resistant to this isolate. Line Lr10, which offers little protection in the field when deployed on its own, was susceptible to isolate WBRS-04-01. The temperature–sensitive resistances of Lr13 and Lr37 were more effective 25^{o}C and 10^{o}C respectively. Lr13, like Lr10, offers little field protection when deployed singly but resistance conferred by Lr37 remains effective.

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 separate field nurseries. The susceptible spreader cv Arina was artificially inoculated with isolate WBRS-03-11 (WBV-1,7) which was cultured from a sample of cv. Claire. This isolate had infected the highly resistant cv. Claire in 2003 adult plant, controlled environment tests at quite high levels.
Table 5 and 6 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).
3) Cultivar reactions to specific isolates of the pathogen in controlled environment tests.

Plants were assessed throughout the season on percentage leaf area infected but since infection was almost undetectable early in the season, the Tables show mean data from the last two assessments only. Note was also made of reaction type classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4).

Results

Winter Wheats (Table 5): High levels of brown rust built up on the spreader cv. Arina that was also used as the susceptible check. However the majority of the test cvs showed little, if any, disease.
Except for cv. Huntsman (WBR-5) and the susceptible check, cv. Arina, all cvs were either resistant or infected at low levels. They included cvs Clement (WBR-1/ Lr26) and Sterna (WBR-7/ Lr3) although the isolate introduced into the nursery was previously identified, in seedling tests, as carrying the matching virulences and also infected the Thatcher lines Lr26 and Lr3 in the spring wheat nursery (below). The low levels of disease shown by cvs Clement and Sterna suggest that cv Arina (the spreader) may have been contaminated by endemic inoculum that replaced or severely ‘diluted’ the artificially introduced isolate WBRS-03-11. In support of this suggestion, cv. Huntsman is postulated to have Lr13, an adult plant resistance widely deployed in European wheat cvs and which, on its own, offers little protection in the field. However, cv. Claire was, as mentioned previously, susceptible to isolate WBRS-03-11 in controlled environment tests so that the low level of disease it developed in the nursery may be explained by establishment of avirulent endemic inoculum within the nursery. Further field tests are therefore needed.
Cvs Steadfast and Welford are postulated to carry Lr10 and Lr37 based on the association of these genes with stripe resistances identified in the cvs. They have previously been identified as also carrying Lr26.

Spring Wheats (Table 6): As in the winter nursery, high levels of disease built up on the spreader cv. and the susceptible check, cv. Thatcher.
The differential cvs Sappo (WBR-3) and Halberd (WBR-4) were resistant to isolate WBRS-03-11 which was not identified as carrying either of the matching virulences in seedling tests.
Of the recommended spring wheats all, except cv. Chablis, have disease ratings of 8 or 9 (resistant) and showed no visible signs of infection. Isolate WBRS-03-11 carries WBV-7 but cv. Chablis which has the corresponding resistance WBR-7 (Lr3) was only infected at a low level. However cv. Chablis carries additional adult plant resistance effective against some WBV-7 pathotypes.
The resistances of the Thatcher-backcross lines Lr9, Lr17, Lr19 and Lr24 were effective as they have been in previous years against other isolates. Lr17, however, showed moderate levels of a resistant infection type.
Lines Lr21, Lr23 and Lr37 expressed lower disease levels than the other susceptible lines. Of these Lr21 has, in recent years, shown moderate to high levels of rust in field nurseries although matching virulence in the pathogen population has fluctuated in frequency between years since 2001. It is not thought that this gene is deployed in any currently recommended cvs although seedlings of line Lr21 and some current cvs did react similarly to the 2003 survey isolates (Jones, 2004). Line Lr23 has an overall, temperature-sensitive resistance that has remained effective at 25^{o}C in controlled environment tests but in the field generally shows low levels of disease which may be of a mixed reaction type. The adult plant, temperature-sensitive resistance of Line Lr37, although overcome at moderate levels (mixed reaction type) by an isolate in a field nursery in 2003, was infected at low levels by isolate WBRS-03-11 in 2004. Resistance conferred by this gene and carried by several popular cvs remains effective.
The remaining Lr lines, including the widely deployed genes Lr10, Lr13 and Lr26, were susceptible although there were quantitative differences in disease levels.

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Table 4 Percentage flag leaf affected and †reaction types of adult plants of winter and spring wheats to specific isolates of leaf rust at 10°C and 25°C

Cv. [1-9 rating]	Postulated Lr genes	Group	ISOLATE WBRS-04-01 ▪(WBV-1,7) Adult Plant 10°C	WBRS-04-01 ▪(WBV-1,7) Adult Plant 25°C	WBRS-04-02 ▪(WBV-0) Adult Plant 10°C	WBRS-04-02 ▪(WBV-0) Adult Plant 25°C
Tybalt [9]		1	0	0	0	0
Robigus [9]			0	0	0	0
Glasgow [9]			0	0	0	0
Paragon [9]		2	0	28	0	20
Belvoir [8]			0	25	0	3
Morph [7]			3R	5	15R	3
Exeter		3	25 MR	22 MR	20 MR	28 MR
Wizard [9]			8 MR	25 MR	2 MR	20 MR
Richmond [9]			4 MR	23 MS	9 MR	25 MR
Ashby [8]			5 MR	25 MS	10 MR	23 MR
Gladiator [8]	26+	4	28 MS	25 MR	1	2
Napier [8]	(10,26,37)		13 MR	23 MS	0.1	1
Savannah [8]	(26,37)		20 MR	28	1	3
Claire [8]			12 MR	8	0.1	3
Defender		5	28 MS	3 MR	15	20 MR
Atlanta			25	15 MR	30	25 MR
Cordiale[4]		6	23 MS	23	15MR	23MR
Lr10		7	35	25	33 MR	18 MR
Lr13			25	25 MR	25 MR	20 MR
Lr26			25	23	25 R	3
Lr37			38 MR	30 MS	28 R	20 MR
Thatcher			35	28	23	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.
[1-9] rating: 1 = susceptible; 9 = resistant.

Table 5 †Percentage leaf affected of winter wheat cvs in a field isolation nursery inoculated with *Puccinia recondita* isolate WBRS-03-11 (WBV-1,7) in 2004

Cultivar [1-9 rating]	WBR	Postulated Lr genes	▪Resistance type	% leaf area affected
Clement	1	26	OR	2
Fundin	2	17b	OR*	4
Huntsman	5	13	APR	16
Gamin	6		APR	Trace
Sterna	7	3a+	OR*+APR	Trace
Ranger	8		APR	0
Avalon	9		APR	1
Arina	0	13?		40
Richmond [9]			OR*	0
Robigus [9]			OR	0
Wizard[9]			OR*	0
Napier [8]		(10,26,37)	OR	0.2
Access [8]		(10,26,37)	OR	0
Savannah [8]		(26,37)	OR	Trace
Claire [8]			APR	0
Gladiator [8]		26+	OR	0
Xi19 [8]			OR*	0
Glasgow [8]			OR	0
Nijinsky [7]				0
Istabraq [7]				0
Smuggler [7]				0
Malacca [7]		10,13(37?)	APR	0
Hereward [6]		10,13	OR	0
Einstein [6]		(10)		0
Brompton [6]		26	OR	0.2
Option [5]			*	0
Tanker [5]		26+	OR	0.1
Welford [6]		26(10,37)	OR	0
Deben [5]			OR*	0
Solstice [5]			*	1
Dickson [4]			APR	0.2
Consort [4]		10,13	*	1
Soissons [3]		14a	APR	0.1
Riband [3]		13,17b		0.2
Steadfast		26(10,37)	OR	0
Dart				0
Defender			*	0
Exeter			APR	0
Ambrosia [8]		26	OR	0
Scorpion 25				Trace
Bentley				Trace
Cordiale [4]				0.2
Atlanta				0.5
Senator				0.7

†Mean of 3 replicates, 2 assessment dates, for total plant leaf area infected.
▪APR = adult plant resistance; OR = overall resistance; * temperature sensitive resistance.
( ) postulated Lr genes based on links to resistances for stripe rust.
[1-9] rating: 1 = susceptible; 9 = resistant.

Table 6 †Percentage leaf affected of spring wheat cvs in a field isolation nursery inoculated with *Puccinia recondita* isolate WBRS-03-11 (WBV-1,7) in 2004

Cultivar [1-9 rating]	WBR	Postulated Lr genes	▪Resistance type	% leaf area affected
Sappo	3	20	OR*	Trace
Halberd	4	20	OR*	Trace
Wallace [9]			OR	0
Paragon [9]			APR*	0
Tybalt [9]			OR	0
Belvoir [8]			OR*	0
Ashby [8]			OR*	0
Morph [7]			*	0
Chablis [6]		3a+	OR*+APR	2
Lr1				12
Lr2a				16
Lr2b				18
Lr2c				23
Lr3				14
Lr9				0
Lr10				30
Lr11				18
Lr13				23
Lr15				36
Lr17				12R
Lr19				0
Lr21				2
Lr23				5
Lr24				0
Lr26				30
Lr28				26
Lr37				2
Thatcher				45

†Mean of 3 replicates, 2 assessment dates, for total plant leaf area inffected
All reaction types susceptible unless indicated by (. R = resistant)
▪APR = adult plant resistance; OR = overall resistance; * temperature sensitive resistance
[1-9] rating: 1 = susceptible; 9 = resistant.

BROWN RUST OF BARLEY

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Pathotypes identified from the 2004 isolates were complex carrying between seven and nine virulence factors. None of the current winter barleys appear to carry race specific resistance but some have partial adult plant resistance which confers good levels of protection. Several of the HGCA Recommended List spring barleys are postulated as carrying BBR-3 and some to possess additional genetic factors contributing to partial adult plant resistance. They include the newly recommended cv. Waggon and the potential new cv. Minstrel. Should cvs relying solely on BBR-3 for protection be exposed to pathotypes carrying the matching virulence, BBV-3, then it is likely that they will become heavily infected. The newly recommended cvs Westminster and Tocada carry BBR-10 (Rph10), and virulence to this resistance is present at a very high frequency. Cv. Vada continues to confer good levels of partial resistance.

INTRODUCTION

Brown rust levels were very low in 2004 and well below their 10 year mean (Crop Monitor: Winter Barley Survey, provisional data 2004). Samples were received from 33 winter and 5 spring barley cvs (Table1). Twenty-five of the winter samples were collected from trial plots grown at NIAB, Cambridge. The remainder were from Norfolk (3), Scotland (2), Wales (1), Oxford (1) and Kent (1). Of the spring barleys, four were from Kent and one from a disease nursery at IGER, Aberystwyth.

SEEDLING TESTS WITH 2004 ISOLATES

Methods

Isolates cultured from 20 samples were tested on the standard set of 10 cvs listed in Table 2 and which carry different, identified Rph genes for resistance to brown rust. Also included in tests were the spring barley cvs Cellar, Kirsty and Carafe which have previously expressed high levels of resistance but whose BBR characteristics are unclear.

Table 1 Source cvs of 2004 brown rust samples

Barley cv. [1-9 rating]	No. of samples	Barley cv. [1-9 rating]	No. of samples	Barley cv. [1-9 rating]	No. of samples
Winter cvs					
Colossus [3]	6	Aquarelle	2	Rattle	1
Amarena [8]	2	Haka [7]	2	Flagon [8]	1
Kingston	2	Pearl [7]	2	**Spring cvs**	
Camion [5]	2	Saffron [7]	1	Midas	1
Carat [5]	2	Scylla [6]	1	Cellar [8]	1
Regina [8]	2	Spectrum [5]	2	Chalice [4]	1
Pict [7]	2	Siberia [5]	1	Static [8]	1
Sequel [5]	2	Cannock [5]	1	Riviera [6]	1

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

Cultivar	BBR Factor	Gene (Rph)	Ranking for octal notation
Sudan	1	1	1
Peruvian	2	2	2
Ribari	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
Hordeum 2596	9	9	9
Trumpf	10	12	10

Results

Virulences, and their frequencies, identified from the 2004 isolates are given in Table 3 where they are compared with those from previous years. Only resistance conferred by BBR-7 and carried by the differential cv. Cebada Capa was effective against all the isolates.

BBV-3, carried by 40% of the 2004 isolates has, with the exception of 2003 when there was an increased frequency, probably due to unrepresentative sampling, remained at a fairly stable frequency over the last 10 years. Prior to that it was only identified at very low frequencies. The increased frequency of BBV-3 during the mid-1990s appears to correspond with the recommendation of spring barleys, e.g cvs Alexis, Chime and more recently e.g. Static, Kirsty, that carry the matching resistance, BBR-3, although in some cvs this is combined with other genetic factors conferring partial resistance. Cvs Cellar, Kirsty and Carafe were resistant to isolates lacking virulence BBV-3 but expressed a susceptible, sometimes mixed, infection

type to isolates carrying this virulence. Currently 43% of the spring barleys on HGCA Recommended List are thought to carry BBR-3 either on its own or in combination with additional resistance and are estimated to have occupied 13.5% of the spring barley hectarage in 2004 (NIAB 2004). Virulence to BBR-10 (BBV-10) has increased in frequency over recent years and was carried by all the 2004 isolates. BBV-10 virulence frequency increased rapidly during the 1980s due to the very large area sown to cv. Triumph (BBR-10) and its derivatives, but was found at reduced levels between 1998 and 2002. Currently recommended spring barleys that appear to carry the BBR-10 resistance include cvs Optic, Spire and Tocada, but it is sometimes combined with additional resistance as in cvs Decanter and Power. It is estimated that about 40% of the area sown to spring barley in 2004 was to cvs carrying BBR-10, of which around 34% was to cv. Optic (NIAB 2004)
None of the current winter barleys is thought to carry race specific resistance.

Table 3 Frequencies* of individual virulences in 2004 compared with representative data from previous years

	Frequency					
BBV - Year	1984	1992	1996	1998	2002	2004
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	0.08	0.42	0.23	0.36	0.40
4	1.00	1.00	1.00	1.00	1.00	1.00
5	0.58	0.71	0.84	0.96	0.82	0.75
6	0.96	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	0.58	0.33	0.68	1.00
10	0.88	0.98	0.50	0.45	0.68	1.00
No. of isolates	24	77	12	27	33	20

*****1 represents 100%

With the increased frequency of BBV-10 and the high frequency of several of the other virulence factors, it is not surprising that the pathotypes identified in 2004 (Table 4) were complex: they carried between 7 (race octal 1653) and 9 (race octal 1677) virulence factors. Increased complexity over recent years is illustrated by frequency of race octal 273. This race was dominant in 1998 when it often appeared to infect winter barleys more severely than more complex pathotypes. It has, however, steadily declined in frequency over recent years and was undetected in 2004. This is presumably because it lacks BBV-10 which is required to overcome the BBR-10 resistance that is widely deployed in current spring cvs. As noted, BBV-10 was carried by all the 2004 isolates.

Table 4 Races and their frequencies* identified from the 2004 isolates compared with representative data from the previous years

Race Octal	BBV factors	Frequency					
		1984	1992	1996	1998	2002	2004
273	1,2,4,5,6,8	0	0	0.34	0.44	0.28	0
633	1,2,4,5,8,9	0.04	0	0	0	0	0
673	1,2,4,5,6,8,9	0.08	0.2	0.08	0	0	0
277	1,2,3,4,5,6,8	0	0	0	0.11	0.04	0
677	1,2,3,4,5,6,8,9	0	0	0.08	0	0	0
1273	1,2,4,5,6,8,10	0	0	0.08	0.08	0	0
1257	1,2,3,4,6,8,10	0	0	0	0.04	0	0
1653	1,2,4,6,8,9,10	0.38	0.25	0.08	0	0.10	0.15
1657	1,2,3,4,6,8,9,10	0	0.04	0.08	0	0.10	0.10
1673	1,2,3,4,5,8,9,10	0.50	0.65	0	0.25	0.24	0.45
1677	1,2,3,4,5,6,8,9,10	0	0.04	0.26	0.08	0.24	0.30
No. of isolates		24	77	12	27	33	20

*1 represents 100%

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 those on the HGCA Recommended Lists (RL) of winter and spring barleys, potential new cvs, outmoded cvs and some of the differential cvs. Two replicates of each cv. were inoculated separately with each of the following isolates:

Isolate	BBV-	Race octal	Origin
BRS-03-23	1,2,4,5,6,8	273	cv. Regina, Cambridge
BRS-97-27	1,2,3,4,6,8,9,10	1653	cv. Fighter, Lincolnshire
BRS-03-25	1,2,3,4,5,6,8,9,10	1677	cv. Pict, Cambridge

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

Seedling tests: Seedlings of spring and winter barley cvs included in adult plant tests, potential new cvs, outmoded cvs and some of the differential cvs were grown in a spore-proofed glasshouse 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.

Results

Winter barleys (Table 5): As adult plants, cvs expressed a range of quantitative responses with disease levels sometimes varying between isolates. Cultivars inoculated with isolates BRS-97-27 and BRS-03-25 showed a greater range in levels of susceptibility than those exposed to isolate BRS-03-23 (the least complex) by which the majority of cvs were infected at similar levels. None of the current HGCA recommended winter barleys are thought to carry race specific resistance but some, e.g cvs Flagon, Kingston, Haka, were infected at low levels by one or other of the isolates and some expressed a mixed reaction.

Spring barleys (Table 6): In Table 6, the spring barley cvs are grouped on the basis of similarities in their interactions with the isolates. Grouping does not necessarily imply that cvs within a group carry a common resistance factor(s).

Group 1: These cvs were susceptible as seedlings and adults. They include cv Vada which carries partial resistance. This cv and its many derivatives e.g. Georgie, Lofa Abed, Sundance were widely grown during the1970s and early 1980s before cv. Triumph, which carries a race specific resistance, and its derivatives dominated the market. The Vada resistance continues to confer adult plant protection and cv. Vada was infected at much lower levels than other Group 1 members.
Group 2: These cvs responded similarly to the isolates as the differential cv. Simon which carries resistance factor BBR-3(Rph3). They were either resistant to, or infected at very low levels, by isolates BRS-97-27 and BRS-03-23 but susceptible to BRS-03-25, the only isolate to carry virulence factor BBV-3.
Group 3: It is postulated that these cvs, like those in the previous group, carry BBR-3 but differ from them in possessing additional resistance(s) which is effective at the later growth stages to isolates carrying BBV-3. Thus members of Group 3, which include the recommended cvs Static, Carafe, Waggon and Cellar and the potential new cv. Minstrel were seedling susceptible to isolate BRS-03-25 but expressed a resistant infection type as adult plants. Although the disease ratings of cvs in Groups 2 and 3 are similar, it would be expected that cvs in Group 3 would be much more resistant than Group 2 if both were exposed to BBV-3 pathotypes..
Group 4: These cvs, including the differential Trumpf (BBR-10), were susceptible to isolates BRS-97-27 and BRS-03-25 but resistant to isolate BRS-03-23 (race octal 273), the only one lacking virulence factors BBV-9 and BBV-10 which are usually found in association. Some of the cvs, Spire, Tocada, Westminster and Toucan showed quite high areas of leaf affected by BRS-03-23 but gave a resistant or mainly resistant reaction type.
Group 5: As seedlings, cvs Decanter and Power showed a similar pattern of responses to the isolates as members of Group 4, suggesting they carry resistance factor BBR-10. However, unlike Group 4, adult plants expressed a resistant or mainly resistant reaction type to all the isolates. It appears therefore that they carry additional adult plant resistance effective against these BBV-10 isolates.
Group 6: The differential cv. Quinn (BBR-5) was susceptible to the only isolate (BRS-03-23) carrying the matching virulence BBV-5. It has previously expressed adult plant resistance to some BBV-5 isolates (Jones, 2001).

ADULT PLANT FIELD ISOLATION NURSERIES

Methods

Winter and spring barleys were sown in separate nurseries during the 2003-2004 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. Isolate BRS-03-23 (race octal 273), ex cv. Regina, Cambridge, was introduced artificially into the winter nursery. The spring barley nursery was inoculated with isolate BRS-03-25 (race octal 1677) ex cv. Pict, Cambridge, which carries virulence to all the differential cvs except for Cebada Capa (BBR-7).
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 7): All infected cvs were classified as susceptible based on reaction types but they displayed differing levels of susceptibility. Disease levels taken at the final assessment date were similar on the susceptible cvs to those grown in a nursery in 2002 and higher than those recorded in the field in 2003. The highly susceptible cv. Colossus, which has a disease rating of 3, showed the highest rust levels with about 40% leaf area affected. Some cvs expressed good levels of partial resistance. These included cvs Haka and Kingston, that were also infected at low levels in previous years nurseries, and the newly recommended cvs Flagon and Saffron. Cv. Amarena, which has a disease rating of 8, developed no visible disease. It was however highly susceptible in glasshouse tests (Table 5) to the same isolate, BRS-03-23. Further studies are needed to explain this apparent inconsistency.

Spring barleys (Table 8): High levels of disease, similar to those in 2003, built up on the susceptible spring barley cvs. They expressed a range of quantitative, susceptible or resistant responses to the introduced pathotype. The differential cv. Trumpf (BBR-10) was one of the most heavily diseased with cvs Toucan, Westminster, Spire and Optic, postulated as carrying the same resistance (Table 6), also quite heavily infected. The newly recommended cv. Tocada, also thought to carry BBR-10, was slightly less heavily infected. Cvs Decanter and Power thought to carry BBR-10 plus adult plant resistance, on the basis of their glasshouse reactions (Table 6), showed similar leaf areas infected to Tocada but in cv. Power the reaction type was mainly resistant.
Cvs Simon (BBR-3) and Henley, also thought to carry BBR-3, showed only moderate levels of infection but other cvs, thought from glasshouse tests (Table 6) to carry the same resistance gene, showed different levels of resistance. Thus, cv. NFC Tipple gave a similar area infected but showed a mixed reaction type, and cv Oxbridge showed lower leaf area infected. However, cvs Prestige and Wicket were relatively susceptible and although these cvs have high (resistant) disease ratings, exposure to BBV-3 pathotypes could cause serious disease. Cv. Kirsty reacted similarly to these cvs in glasshouse tests (Table 6) but in the field it was resistant. Its field response therefore suggests that as well as BBR-3 it carries additional adult plant resistance. From the nursery and the glasshouse tests, this appears also to be the case in cvs Static, Waggon, Cellar, Carafe and Minstrel.
Of the other cvs, Rebecca, Doyen and Macaw showed relatively low disease levels similar to that of cv. Vada whose partial resistance remains effective.

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Table 5 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.

	Isolate					
Cultivar [1-9 rating]	BRS-97-27 (BBV-1,2,4,6,8,9,10) Race octal 1653		BRS-03-23 (BBV-1,2,4,5,6,8) Race octal 273		BRS-03-25 (BBV-1,2,3,4,5,6,8,9,10) Race octal 1677	
Colossus [3]	50	(S)	25	(S)	40	(S)
Siberia [5]	50	(S)	30	(S)	38	(S)
Scylla [6]	35	(S)	25	(S)	30	(S)
Amarena [8]	35	(S)	25	(S)	20	(S)
Sequel [5]	35	(S)	20	(S)	25	(S)
Pict [7]	25	(S)	30	(S)	30	(S)
Regina [8]	25	(S)	30	(S)	30	(S)
Rattle	30	(S)	35	(S)	20	(S)
Nocturne	25	(S)	25	(S)	30	(S)
Aquarelle	20	(S)	25	(S)	25 I	(S)
Carat [5]	15	(S)	30	(S)	8 MS	(S)
Spectrum [5]	13	(S)	2	(S)	6	(S)
Saffron [7]	10 MS	(S)	20	(S)	20	(S)
Camion [5]	5	(S)	15	(S)	20	(S)
Haka [7]	0	(S)	10	(S)	20 MR	(S)
Cannock [5]	5	(S)	20	(S)	10	(S)
Pearl [7]	5	(S)	8	(S)	10	(S)
Kingston	0	(S)	5	(S)	5	(S)
Flagon [8]	5 MR	(S)	15	(S)	2 I	(S)
Fanfare [8]	-	(S)	-	(S)	-	(S)
Colibri	-	(S)	-	(S)	-	(S)
Surtees	-	(S)	-	(S)	-	(S)
NSL 00-6692	-	(S)	-	(S)	-	(S)
Fahrenheit	-	(S)	-	(S)	-	(S)
CPBT B68	-	(S)	-	(S)	-	(S)
Boost	-	(S)	-	(S)	-	(S)
NORD 99565/17	-	(S)	-	(S)	-	(S)
CPBT B70	-	(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; I = intermediate.

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Table 6 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 [1-9 rating]	Group	Isolate: BRS-97-27 (BBV-1,2,4,6,8,9,10) Race octal 1653		Isolate: BRS-03-23 (BBV-1,2,4,5,6,8) Race octal 273		Isolate: BRS-03-25 (BBV-1,2,3,4,5,6,8,9,10) Race octal 1677	
Riviera [6]	1	28	(S)	25	(S)	25	(S)
Troon [6]		20	(S)	35	(S)	18	(S)
Rebecca [5]		20	(S)	20	(S)	18	(S)
Chalice [4]		18	(S)	28	(S)	25	(S)
Vada		9	(S)	7	(S)	5	(S)
Simon BBR-3	2	0.1	(R)	2	(R)	17	(S)
Wicket [8]		0.1	(MR)	2	(R)	20	(S)
Kirsty [9]		1 MR	(MR)	2	(MR)	18	(S)
Oxbridge [7]		0.3	(R)	0.2	(R)	18	(S)
Henley		10 R	(MR)	4 MR	(R)	15	(S)
Prestige [9]		3 R	(MR)	2	(R)	20	(S)
NFC Tipple [9]		0.5	(R)	0.5	(R)	10	(S)
Static [8]	3	7 R	(MR)	0.4 R	(R)	23 R	(S)
Carafe [9]		0.5	(MR)	0.3 R	(R)	23 MR	(S)
Waggon [9]		0.5 R	(MR)	3 R	(R)	20 R	(S)
Cellar [8]		2 R	(MR)	2 R	(R)	15 MR	(S)
Minstrel		0.5 R		1 MR	(R)	15 MR	(S)
Trumpf BBR-10	4	11	(S)	2 MR	(R)	17	(S)
Westminster [5]		28	(S)	10 R	(R)	19	(S)
Optic [6]		23	(S)	2 MR	(R)	10	(S)
Toucan		15	(S)	20 R	(R)	18	(S)
Tocada [4]		19	(S)	13 R	(R)	13	(S)
Spire [5]		18	(-)	13 R	(-)	13	(-)
Power [6]	5	14 R	(S)	0.5 MR	(R)	3 MR	(S)
Decanter [6]		25 R	(S)	15 MR	(R)	20 MR	(S)
Quinn BBR-5	6	1 MR	(R)	13	(S)	8	(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.

Table 7 *Mean total percentage leaf area affected and reactions type of winter barley cultivars to brown rust in a field nursery in 2004

Cultivar [1-9 rating]	% Infection BRS-03-23 (Race 273)	Reaction type†
Colossus [3]	40	S
Siberia[5]	35	S
Cannock[5]	30	S
Carat [5]	30	S
Regina [8]	25	S
Aquarelle	20	S
Scylla [6]	12	S
Camion [5]	10	S
Spectrum [5]	10	S
Pict [7]	8	S
Sequel [5]	8	S
Nocturne	7	S
Pearl [7]	6	S
Rattle	4	S
Kingston	2	S
Flagon [8]	2	S
Saffron [7]	1	S
Haka [7]	1	S
Amarena [8]	0	R

*Mean of 4 replicates, final assessment date

†0-2 type reaction – resistant (R) 3-4 type reaction – susceptible (S)
When more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant
[ ] Resistant rating: 1 = susceptible; 9 = resistant

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Table 8 *Mean total percentage leaf area affected and reactions type of spring barley cultivars to brown rust in a field nursery in 2004

Cultivar [1-9 rating]	BBR factor	% Infection BRS-03-25 (Race 1677)	Reaction type†
Trumpf	10	25	S
Prestige [9]		25	S
Toucan		25	S
Chalice [4]		20	S
Spire[5]		20	S
Riviera [6]		18	S
Westminster [5]		18	S
Wicket [8]		18	S
Troon [6]		15	MS
Optic [6]		15	S
Minstrel		15	MR
NFC Tipple [9]		15	MS
Henley [8]		10	S
Simon	3	10	S
Quinn	5	10	S
Power [6]		10	MR
Tocada [4]		10	S
Rebecca [5]		8	S
Cellar [8]		8	R
Decanter [6]		7	S
Oxbridge [7]		5	S
Kirsty [9]		4	MR
Waggon [9]		3	R
Doyen [7]		3	S
Vada		3	S
Macaw		2	S
Cocktail [8]		1	S
Static [8]		1	MS
Carafe [9]		0.1	S

*Mean of 4 replicates, final assessment date

†0-2 type reaction – resistant (R) 3-4 type reaction – susceptible (S)
When more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response.
MS = mixed susceptible; MR = mixed resistant
[ ] Resistant rating: 1 = susceptible; 9 = resistant

CROWN RUST OF OATS

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No samples were received in 2004.

Ten varieties of oats, *Avena sativa* L. (Table1), have been used in the U.K.Cereal Pathogen Virulence Survey since 1967 to differentiate oat crown rust. Subsequently, virulence to Appler, Bond and Saia has been at a high frequency and these are often combined in Race 251, the dominant form in recent years. Virulence has been identified at lower frequencies to Anthony, Landhafer, Trispernia, and Ukraine and in just a few isolates to Santa Fe and Bondvic. The virulences have been identified in various combinations in the pathogen but very few of the UK pathotypes have overcome the resistances of more than four of the differential cvs. It is not thought that resistances carried by the differential cvs have been widely deployed in commercially bred cvs although cv. Trafalgar, recommended during the 1980s, had Landhafer as an ancestor. Virulence to the majority of the differential cvs has therefore remained at a low frequency for nearly 40 years probably due to little host imposed selection. The set of seedling test cvs are of little relevance to current commercial cvs and breeding programmes so a revised set of differentials for crown rust of oats is to be introduced.

The new set comprises 21 near-isogenic lines (Table 1) many of which have been used in Canada to identify increased virulence in the pathogen population (Chong and Zegeyo, 2004). The majority of the lines are backcross lines of the universally susceptible oat variety Pendek possessing different, single genes (Pc) for crown rust resistance derived from *Avena sterilis*. The line possessing Pc14 is the cv. Ascencao (Harder, 1980). The new set of differential lines should make the crown rust survey more meaningful to oat breeders as it is thought that some of these Pc genes are being utilised in breeding programmes.

Table 1 Outmoded differential cvs and the new set of near-isogenic lines for identification of oat crown rust virulence.

Outmoded differential cultivars (1967-2004)	Revised set of differential (Pc) lines	
Anthony	Pc 14	Pc 55
Victoria	Pc 35	Pc 56
Appler	Pc 38	Pc 58
Bond	Pc 39	Pc 59
Landhafer	Pc 40	Pc 60
Santa Fe	Pc 45	Pc 61
Ukraine	Pc 46	Pc 62
Trispernia	Pc 47	Pc 63
Bondvic	Pc 48	Pc 68
Saia	Pc 50	Pc 96
	Pc 54	

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RHYNCHOSPORIUM OF BARLEY

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The frequencies of virulence factors BRV-1, BRV-2 and BRV-7 were lower than in recent years. This was probably due to the higher proportion of tested isolates coming from recommended spring barleys none of which carry the matching race specific resistances. BRV-5, BRV-6 and BRV-8 remain at low levels in the population but should cvs carrying the matching resistances (e.g. Rebecca and Westminster BRR-5 and Doyen BRR-8) become more widely grown then it is very likely that there will be a rapid increase in the frequencies of the corresponding virulence factors. The newly recommended winter cv. Amarena and the potential new cvs Boost, Fahrenheit and Colibri were seedling resistant to isolates carrying a range of virulences. Cv.Amarena also expressed good levels of field resistance as did cv.Cannock which may carry BRR-2 plus additional resistance that is effective against some BRR-2 pathotypes. The spring barley cvs Westminster and Minstrel carry BRR-5. The newly recommended cvs Oxbridge and Power, which were very susceptible in glasshouse tests, were infected at relatively low levels in the field.

INTRODUCTION

Leaf blotch was the dominant foliar disease of winter barley in 2004 (Crop Monitor, Winter Barley Survey, 2004). Fifty-two winter (Table 1) and 39 spring (Table2) barley samples were received. Geographically, 43 samples were from 2 testing sites in Northern Ireland. The remainder were collected across 13 counties of England and Scotland (Table3).

Table 1 Source winter barley cultivars of 2004 leaf blotch samples and their disease resistance rating [1= highly susceptible; 9 = highly resistant].

Cv. [1-9 rating]	No. of samples	Cv. [1-9 rating]	No. of samples	Cv. [1-9 rating]	No. of samples
Haka [5]	8	Scylla[7]	2	Flagon [8]	1
Pearl [7]	7	Regina [7]	2	Jewel [8]	1
Carat [7]	3	Cannock [8]	2	Amarena [8]	1
Saffron [6]	3	Antonia	2	Siberia [8]	1
Spectrum[7]	3	Camion [7]	2	Heligan	1
Pict [8]	3	Aquarelle	1	Rattle	1
Sequel [8]	3	Nocturne	1	Unknown	1
Kingston	3				

Table 2 Source spring barley cultivars of 2004 leaf blotch samples and their disease resistance rating [1= highly susceptible; 9 = highly resistant].

Cv. [1-9 rating]	No. of samples	Cv. [1-9 rating]	No. of samples	Cv. [1-9 rating]	No. of samples
Cellar [4]	3	Doyen [8]	2	Henley	1
Optic [4]	3	Tocada [4]	2	Power [6]	1
Troon [4]	3	NFC Tipple	2	Toucan	1
Carafe [4]	2	Decanter [5]	1	Waggon [4]	1
Spire [4]	2	Chalice [5]	1	Minstrel	1
Prestige[4]	2	Cocktail [6]	1	Macaw	1
Riviera[6]	2	Static [5]	1	Oxbridge [7]	1
Kirsty[5]	2	Westminster[8]	1	Wicket [6]	1
Rebecca[7]	2				

Table 3 Geographic origins of 2004 leaf blotch samples

County of origin	No. of samples	County of origin	No. of samples	County of origin	No. of samples
Tyrone	24	Kent	4	W.Midlands	1
Londonderry	19	Midlothian	3	Herts	1
Cambs	17	Perth	2	E.R.Yorks	1
N. Yorks	5	Devon	2	Norfolk	1
Aberdeen	4	Glos	1	Unknown	2
Hereford	4				

SEEDLING TESTS WITH YEAR 2004 ISOLATES

Methods

Isolates cultured from 44 samples were inoculated onto seedlings of the standard set of differential cultivars carrying different, specific resistant genes (Table 4). Post-inoculation plants were incubated and assessed as described previously (Jones and Newton, 2004)

Table 4 Differential test cultivars for *Rhynchosporium secalis* and their rankings for octal notation.

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

Results

Table 5 compares the frequencies of individual virulences identified from the 2004 isolates with those of previous seasons. Virulence factors BRV-1 and BRV-2, which appear to be associated, as their frequencies have been identical over many years, were at a reduced frequency (67%) in 2003 and declined further (25%) in 2004. This is probably because over half of the samples tested in 2004 were from spring barleys none of which carry the matching resistances BRR-1 or BRR-2. Also, of the 20 isolates cultured from winter barleys only seven were from cvs postulated as carrying these resistance factors. Likewise, the reduced frequency of BRV-7, that overcomes the resistance of the differential cv. Pirate (BRR-7), is also probably due to the higher than usual proportion of isolates from spring barleys, none of which carry the matching resistance BRR-7.

BRV-4 which has been at a high frequency since it was first identified in the early 1980s was found in 93% of the 2004 isolates. The matching resistance BRR-4 has since been carried by many popular cvs, e.g Puffin and Pearl, several of which have the differential cv. Igri (BRR-4) as an ancestor.

BRV-5 and BRV-6, which are usually found in association, remain at a low frequency. Of the 2004 isolates only two samples from cv. Rebecca, collected in Aberdeen and Co.Tyrone, were identified as carrying these virulences. However should cvs carrying one or both of the corresponding resistance factors, BRR-5 and BRR-6, become more popular it is likely that their will be a rapid increase in the frequency of BRV-5 and BRV-6. This was the case in the mid-1990s when BRV-5 increased in frequency due to cv. Pipkin (BRR-5) occupying between 5% and 10% of the winter barley hectarage at that time. Cvs carrying BRV-5 are estimated to have occupied only around 1% of the area sown to spring barley in 2004

One isolate, sampled from cv. Doyen in Aberdeen, carried virulence to the differential cv. Digger (BRR-8). BRR-8 has only been deployed in three Recommended cvs, Pewter, Livet and currently Doyen, since it was first identified in cv. Digger in 1990. The area sown to these has been very low and consequently BRV-8 has remained at a low frequency in the pathogen population. However, as with BRR-5 carriers, should cvs carrying BRR-6 become widely grown then any protection offered by the resistance is unlikely to be durable.

Table 5 Frequencies of individual virulences, 1992-2004

Year	BRV-								No. of isolates
	8	7	6	5	4	3	2	1	
2004	0.02	0.27	0.05	0.05	0.93	*1.00	0.25	0.25	44
2002	0	0.78	0.01	0.03	0.90	1.00	0.90	0.90	73
2000	0.05	0.70	0.05	0.05	0.78	1.00	0.75	0.75	40
1998	0.03	0.42	0.06	0.22	0.67	1.00	0.72	0.72	36
1996	-	0.68	0.18	0.39	0.71	1.00	0.61	0.61	28
1994	-	0.85	0.07	0.15	0.97	0.99	0.88	0.88	67
1992	-	0.50	0.07	0.10	0.86	0.97	0.40	0.40	30

(*1 represents 100%)

The virulence combinations present in the 2004 isolates are shown in Table 6. Race octal 117 (BRV-1,2,3,4,7) has been the prevalent race in recent years but in 2004 the simpler race octal 14 was dominant. Unlike race octal 117 it lacks virulence factors 1, 2 and 7 which were, as mentioned previously, at a reduced frequency in 2004.

Table 6 Virulence factor combinations identified from 2004 isolates

No. of isolates	Differential cultivars in linear order								Race octal
	Digger	Pirate	Osiris	LaMesita	Igri	Athene	Astrix	Armelle	
2	0	0	0	0	0	1	0	0	4
22	0	0	0	0	1	1	0	0	14
6	0	1	0	0	1	1	0	0	114
1	0	0	0	0	0	1	1	1	7
2	0	0	1	1	1	1	0	0	74
4	0	0	0	0	1	1	1	1	17
1	1	0	0	0	1	1	0	0	214
6	0	1	0	0	1	1	1	1	117

1 – susceptible; 0 = resistant

GLASSHOUSE ADULT PLANT AND SEEDLING TESTS WITH SPECIFIC ISOLATES OF *RHYNCHOSPORIUM*

Methods

Adult plant tests: Winter and spring barleys were grown in a spore-proofed glasshouse until full emergence of the flag leaf. Cvs included those on the HGCA Recommended

Lists of winter and spring barleys, potential new cvs and members of the standard differential set. Two replicates of each cv. were inoculated separately with each of the following isolates whose BRV (race octal) characteristics were identified in previous seedling tests:

Isolate	BRV (race octal)	Origin
RS-03-03	1,2,3,4,7 (117)	cv. Cannock, Notts
RS-04-76	3,4,5,6 (74)	cv. Rebecca, Co.Tyrone
RS-04-90	3,4,8 (214)	cv. Doyen, Aberdeen

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

Seedling tests: Cvs tested were those included in adult plant tests, but in addition included some potential new winter and spring barleys and members of the differential set. Plants were grown to the second leaf stage when they were inoculated with the same isolates and incubated under the same conditions as the adult plants. Seedling reactions were assessed by infection levels on the second leaf and classified as resistant (R), susceptible (S) or intermediate (I) (approx.4%-9% infected leaf area).

Results

Cultivars are grouped within Table 7 and Table 8 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). As seen in many years, levels of disease seen on some cvs in glasshouse tests were greater than those seen on the same cvs in field tests.

Winter barleys (Table 7)

Group 1: Those cvs tested as adult plants were infected, although there were differences in disease levels between isolates and cvs. Cv. Pearl, thought to carry BRR-4 on the basis of its ancestry, was infected at low levels suggesting that it may indeed carry this resistance factor, which is often effective at later growth stages even to isolates identified as carrying the matching virulence BRV-4. As seedlings, these cvs were susceptible to all three isolates except for cv. Carat which was infected at low levels and was classified as intermediate. In similar tests with different isolates in 2003 cv. Carat was resistant to an isolate lacking BRV-2 but susceptible to isolates carrying this virulence thus suggesting it has BRR-2. However, in 2004 its susceptible adult plant response to the non-BRV-2 isolates RS-04-76 and RS-04-90 suggests this may not be the case . Also, while cv.:isolate interactions in 2003 tests suggested that cv. Spectrum carries BRR-2, in 2004 it was seedling susceptible to the isolates lacking BRV-2. Further tests are needed to explain its resistance.

Group 2: These cvs were susceptible as adult plants to isolate RS-03-03 (BRV-1,2,3,4,7) but resistant to the 2 isolates lacking BRV-1 and BRV-2. They expressed a similar pattern of responses as seedlings. The reactions of the potential new cvs NSL-00-6692, CPBT 70 and NORD 99565/17 suggest that they, like other members of the group, carry BRR-2. In similar tests in 2003, cv. Cannock, which expresses high levels of field resistance, was seedling resistant to 2 isolates carrying BRR-2 but it had been susceptible as an adult plant and seedling to a BRV-2 isolate in 2002. It may be that this cv. carries

additional resistance effective against some BRV-2 isolates although not to the one used here.
Group 3: Adult plants of the differential cv. Pirate (BRR-7), whose resistance is more readily expressed at later growth stages, were susceptible to isolates RS-03-03 and RS-04-76 although the latter was not identified as carrying the matching virulence, BRV-7, in previous seedling tests. Only isolate RS-03-03 induced a susceptible response on seedling infection levels against the other two isolates being lower and classified as intermediate. The newly recommended cv. Flagon showed a similar pattern of responses.
Group 4: Included within this group is the differential cv. Igri (BRR-4). Its adult plant resistance was effective against all the isolates but as seedlings it expressed a susceptible or intermediate response. On the basis of their pedigrees BRR-4 is thought to have been deployed in several popular cvs over the last 20 years. Generally these cvs have shown good levels of adult plant resistance despite, as mentioned previously, BRV-4 occurring at a high frequency in the pathogen population. Cv. Colossus and the newly recommended cv. Amarena were resistant as adult plants and were only infected, at low levels, by isolate RS-03-03 as seedlings. Seedlings of the potential new cvs Colibri, Fahrenheit and Boost expressed intermediate or resistant reactions.

Spring barleys (Table 8)

Group 1: The cvs of this group that were tested as adult plants were highly susceptible to all isolates. As in previous tests, seedlings of other Recommended List cvs, were also susceptible as adult plants.
Group 2: These cvs were adult plant susceptible to isolate RS-04-76, the only one carrying BRV-5 and BRV-6. These virulence factors are usually associated, and overcome the matching resistance of BRR-5 in the differential cv. La Mesita and BRR-6 carried by cv. Osiris. All the cvs, except for cv. La Mesita, were resistant as seedlings and adult plants to the other two isolates although cv La Mesita was susceptible to them as an adult plant. It is a known characteristic of this differential cv., and some other BRR-5 cvs, that it is susceptible at the later growth stages to isolates not identified as carrying the matching virulence in seedling tests.
Group 3: The differential cv. Armelle (BRR-1) was susceptible only to isolate RS-03-03 (carrying the matching virulence BRV-1). Although very few recommended spring barleys have been identified as carrying BRR-1 virulence to it has been at a high frequency in the population over several years. This is probably because BRR-1 is associated with BRR-2 which has been widely deployed in winter barley cvs.
Group 4: The resistance, conferred by BRR-8, of cvs Digger and Doyen was overcome by one isolate, RS-04-90 (BRV-3,4,8). The other isolates infected these cvs only at very low levels. BRV-8 has remained at a low frequency since it was first identified in 1990 but has been deployed in very few recommended cvs, none of which were widely grown.

ADULT PLANT FIELD ISOLATION NURSERIES

Methods

Winter and spring barley nurseries were grown at a site conducive for the development of leaf blotch during the 2004 season. Cultivars comprised those on the HGCA Recommended Lists of winter and spring barleys, potential new cvs, outmoded cvs and cvs carrying known specific resistances and used as differentials in seedling tests.

Disease arose from endemic inoculum and its development was monitored several times during the season.

Results

Winter barleys (Table 9)

Disease levels on the susceptible cvs were generally lower than in recent years probably due to the lack of rainfall during spring. Cultivars showed a range of quantitative responses with cv. rankings generally confirming their 1-9 disease ratings. The seedling differential cv. Igri (BRR-4) was the most heavily infected although it has expressed good levels of adult plant resistance to the majority of isolates against which it has been exposed in glasshouse tests. Other cvs postulated as carrying BRR-4, on the basis that they have cv. Igri in their ancestry, are cv. Haka and cv. Pearl. Cv. Haka was one of the most heavily infected cvs within the 2004 nursery, as it was in field nurseries in the previous two years. It was also highly susceptible to isolate RS-03-03 (carrying BRV-4) in 2004 glasshouse tests (Table 7). Cv. Pearl, however, showed lower levels of infection in the field nursery and in the 2004 adult plant glasshouse tests (Table7). Cultivars postulated as carrying BRR-2 were generally infected at relatively low levels. The majority of these cvs appear to have other genetic factors contributing to partial adult plant resistance. The outmoded cv. Leonie (BRR-5) and the previously field resistant cv Cannock, which may carry BRR-2 plus additional resistance, were highly resistant.

Spring barleys (Table 10)

Disease levels on the susceptible cvs were similar to those of the previous two years. Cultivars differed in the level of disease they developed with cv. rankings generally confirming their 1-9 disease ratings. The newly recommended cvs Power and Oxbridge were infected at relatively low levels although neither appears to have a major gene resistance as both were heavily infected as seedlings and adult plants in glasshouse tests when exposed to isolates carrying different ranges of known, specific virulences (Table8). It may be that they carry partial adult plant resistance which is more readily expressed under field conditions. The BRR-5 recommended cvs Westminster and Rebecca showed high levels of resistance but the potential new cv. Macaw, also BRR-5, was more heavily infected with disease levels similar to that of the differential cv. La Mesita (BRR-5). The differential cv. Armelle (BRR-1) was resistant to the endemic inoculum. None of the current recommended cvs carry BRR-1. The BRR-8 cvs Digger and Doyen were resistant as was the BBR-6 carrier cv. Osiris.

ADULT PLANT FIELD NURSERY AT SCRI

Methods

A nursery, comprising cvs from the 2004 HGCA Recommended List of spring barleys, together with winter and spring barleys carrying known specific resistances, was sown during the spring of 2004. Disease was allowed to build up naturally.

Results

Assessments of percentage leaf area infected were made throughout the season. Cultivars showed quantitative variation in disease levels with the most susceptible cvs heavily infected (Table 11). Cultivars carrying known specific resistances were, except for cv. Rebecca, infected at relatively low levels with some, such as Athene (BRR-3) and Pirate (BRR-7) being highly resistant. Cv. Rebecca, postulated as carrying BRR-5, was very susceptible (36% leaf area infected) although it showed only very low level infection at IGER. However, the other BRR-5 cvs in the SCRI nursery, namely Minstrel, Westminster and La Mesita, were infected at relatively low levels. As mentioned previously, it is not unusual for some BRR cvs to be highly susceptible at later growth stages to pathotypes not identified in seedling tests as carrying the matching virulence. However it is difficult to explain why the differential cv. La Mesita was infected at only low levels as it is usually the most susceptible of all the BRR-5 carriers when exposed to such pathotypes.

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Table 7 *Percentage flag leaf affected and reaction types of seedlings ( ) of winter barley cultivars inoculated with specific isolates of *Rhynchosporium secalis* in glasshouse tests.

Cultivar/isolate [1-9 rating]	Group	RS-03-03 BRV-1,2,3,4,7 (Race octal 117)		RS-04-76 BRV-3,4,5,6 (Race octal 74)		RS-04-90 BRV-3,4,8 (Race octal 214)	
Haka [5]	1	50	(S)	23	(S)	10	(S)
Scylla [7]		25	(S)	55	(S)	45	(S)
Rattle		28	(S)	50	(S)	35	(S)
Saffron [6]		25	(S)	38	(S)	40	(S)
Camion [7]		20	(S)	28	(S)	18	(S)
Spectrum		28	(S)	23	(S)	15	(S)
Otter		28	(S)	25	(S)	23	(S)
Athene (BRR-3)		10	(S)	10	(S)	-	(S)
Pearl [7]		5	(S)	7	(S)	3	(S)
Kingston		-	(S)	-	(S)	-	(S)
Surtees		-	(S)	-	(S)	-	(S)
CPBT 68		-	(S)	-	(S)	40	(S)
Spectrum [7]		-	(S)	-	(S)	-	(S)
Carat [7]		15	(I)	15	(I)	10	(I)
Pict [8]	2	33	(S)	0	(R)	0	(R)
Siberia [8]		15	(S)	0	(R)	0	(R)
Sequel [8]		10	(S)	0	(R)	0	(R)
Aquarelle [8]		10	(S)	0	(R)	0	(R)
Astrix (BRR-2)		33	(S)	1	(R)	0	(R)
Nocturne		18	(S)	0	(R)	-	(R)
Regina [7]		-	(S)	-	(R)	-	(R)
NSL-00-6692		-	(S)	-	(R)	-	(R)
NORD 99565/17		-	(I)	-	(R)	-	(R)
Fanfare [5]		-	(S)	-	(R)	-	(R)
CPBT 70		-	(S)	-	(R)	-	(I)
Cannock [8]		-	(S)	-	(R)	-	(R)
Flagon	3	25	(S)	40	(I)	0	(I)
Pirate (BRR-7)		15	(S)	15	(I)	0	(I)
Amarena [5]	4	0	(I)	0	(R)	0	(R)
Colossus [8]		1	(I)	0	(R)	0	(R)
Fahrenheit		-	(I)	-	(R)	-	(R)
Colibri		-	(I)	-	(R)	-	(I)
Boost		-	(R)	-	(R)	-	(R)
Igri (BRR-4)		-	(S)	0	(I)	3	(S)

*Adult plants assessed on percentage area of flag leaf infected (- indicates not tested)
Mean of 2 plants

Seedlings assessed on 2nd leaf and classified as
resistant (R), susceptible (S), or intermediate (I)
[ ] Disease resistance rating: 1 = susceptible; 9 = resistant

Table 8 *Percentage flag leaf affected and reaction types of seedlings ( ) of spring barley cultivars inoculated with specific isolates of *Rhynchosporium secalis* in glasshouse tests.

Cultivar/Isolate [1-9 rating]	Group	RS-03-03 BRV-1,2,3,4,7 (Race octal 117)		RS-04-76 BRV-3,4,5,6 (Race octal 74)		RS-04-90 BRV-3,4,8 (Race octal 214)	
Cellar [4]	1	70	(S)	75	(S)	70	(S)
Tocada [4]		70	(S)	70	(S)	65	(S)
Toucan		75	(S)	75	(S)	75	(S)
Henley		70	(S)	65	(S)	80	(S)
NFC Tipple [5]		70	(S)	70	(S)	60	(S)
Waggon [4]		65	(S)	70	(S)	70	(S)
Oxbridge [7]		60	(S)	45	(S)	50	(S)
Power [6]		55	(S)	70	(S)	55	(S)
Wicket [6]		50	(S)	50	(S)	40	(S)
Macaw		50	(S)	55	(S)	50	(S)
Optic [4]		-	(S)	-	(S)	-	(S)
Prestige [4]		-	(S)	-	(S)	-	(S)
Spire [4]		-	(S)	-	(S)	-	(S)
Troon [4]		-	(S)	-	(S)	-	(S)
Carafe [4]		-	(S)	-	(S)	-	(S)
Decanter [5]		-	(S)	-	(S)	-	(S)
Riviera [5]		-	(S)	-	(S)	-	(S)
Chalice [5]		-	(S)	-	(S)	-	(S)
Static [5]		-	(S)	-	(S)	-	(S)
Kirsty [5]		-	(S)	-	(S)	-	(S)
Rebecca [7]	2	0	(R)	65	(S)	1	(R)
Minstrel		0	(R)	55	(S)	0	(R)
Westminster [8]		0	(R)	50	(S)	0	(R)
La Mesita BRR-5		40	(R)	40	(S)	15	(R)
Osiris BRR-6		0	(R)	35	(S)	0	(R)
Armelle BRR-1	3	25	(S)	0	(R)	0	(R)
Digger BRR-8	4	2	(R)	0	(I)	65	(S)
Doyen [8]		3	(R)	2	(R)	75	(S)

*Adults plants assessed on percentage area of flat leaf infected (- indicates not tested)
Mean of 2 plants
Seedlings assessed on 2nd leaf and classified as
Resistant (R), susceptible (S) or intermediate (I)
[ ] Disease resistance rating: 1 = susceptible; 9 = resistant

Table 9. *Mean percentage of total leaf area of winter barley cultivars affected by *Rhynchosporium secalis* in a field isolation nursery in 2004

Cultivar [1-9 rating]	Postulated BRR factor	% total leaf area infected
Igri	4	18
Athene	3	16
Haka [5]	4	13
Carat [7]	2	11
Spectrum [7]	2?	10
Scylla [7]		8
Regina [7]	2	8
Otter		6
Pirate	7	6
Pearl [7]	4	5
Camion [7]	4	5
Colossus [8]	2	4
Sequel [8]	2	4
Amarena [8]		4
Rattle		4
Pict [8]	2	4
Kingston		3
Flagon [8]	7?	3
Aquarelle	2	3
Astrix	2	3
Nocturne		3
Saffron [6]		2
Leonie [8]	5	0.5
Cannock [8]	2+?	0.5

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

Table 10 *Mean percentage total leaf area of spring barley cultivars affected by *Rhynchosporium secalis* in a field isolation nursery in 2004

Cultivar [1-9 rating]	BRR factor	% total leaf area infected
Carafe [5]		31
Tocada [4]		30
Prestige [4]		29
Waggon [4]		29
Henley		28
Cocktail [6]		25
Cellar [4]		23
Troon [4]		23
Decanter [5]		21
Spire [4]		21
Toucan		20
Chalice [5]		19
Optic [4]		19
NFC Tipple[5]		16
Riviera[5]		15
Static [5]		14
Kirsty [5]		14
Wicket [6]		12
Macaw		11
La Mesita	5	10
Minstrel	5	9
Power [6]		8
Oxbridge [7]		7
Rebecca [7]	5	3
Westminster[8]	5	1
Armelle	1	1
Doyen [8]	8	0.5
Digger [8]	8	0
Osiris	6	0

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

Table 11 *Mean percentage total leaf area affected of barley cultivars by *Rhynchosporium secalis* in a SCRI field nursery in 2004

Cultivar [1-9 rating]	BRR factor	% total leaf area infected
Prestige [4]		46
Waggon [4]		38
Optic [4]		37
Toucan		37
Rebecca [7]	5	36
Kirsty [5]		32
Chalice [5]		28
Riviera [5]		27
Henley		26
NFC Tipple[5]		26
Troon [4]		25
Spire [4]		24
Cellar [4]		23
Static [5]		23
Power [6]		21
Tocada [4]		20
Decanter [5]		20
Macaw		19
Oxbridge [7]		18
Carafe [4]		17
Cocktail [7]		14
Minstrel	5	8
Doyen [8]	8	6
Astrix	2	5
Wicket [6]		5
La Mesita	5	4
Westminster[8]	5	3
Osiris	6	3
Digger	8	2
Armelle	1	2
Igri	4	1
Athene	3	0.2
Pirate	7	0.1

*Mean of 4 assessment dates. SED = 4.35

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

NET BLOTCH OF BARLEY

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Net blotch levels, although below their ten year mean, were at their highest since the year 2000. Cv. Carat was relatively more heavily infected by the 2004 isolates than might be expected from its disease resistance rating. Seedling resistance previously identified in some cvs remains effective but is not always expressed at later growth stages. The potential new cvs Colibri, Surtees and Boost were resistant as seedlings to a mixed inoculum of the 2004 samples.

INTRODUCTION

Net blotch increased during the latter part of the 1970s due to the increased winter barley hectarage and the growing of susceptible cvs. Breeders responded with programmes to incorporate genetic resistance and in 1982 disease ratings for winter barley appeared on the Recommended List. Since the mid 1980s the majority of cvs have shown good resistance although levels of the disease have fluctuated. The increased disease levels seen intermittently over the last 20 years coincide with the large areas sown to one or two susceptible cvs. For example, in the early 1990s net blotch was, in some regions of the UK, at its highest levels for a decade and this coincided with the large area sown (up to 25% of the winter barley hectarage) to the susceptible cv. Puffin. More recently the susceptible cv. Pearl has been widely grown and is estimated to have occupied around 50% of the area sown to winter barley in 2004 (NIAB 2004). However, in recent years net blotch levels have remained low and, although at their highest levels for four years in 2004, disease levels were still below their 10 year mean (Crop Monitor: Winter Barley Survey 2004). The disease can however be locally damaging and there currently exists the threat of increased infection levels, especially in unsprayed crops. Also QoI fungicides have offered effective control in recent years but this may change with the detection of low levels of resistance in isolates collected in south east England, France and Belgium in 2004 (International FRAC QoI working group). During the 1990s the pathogen showed decreased sensitivity to DMI fungicides.

SAMPLES RECEIVED 2004

Thirty-three samples were received from a range of winter barley cvs (Table 1) and their geographic origins are given in Table 2.

Table 1 Source winter barley cultivars of 2004 net blotch samples

Cv. [1-9 rating]	No of Samples	Cv. [1-9 rating]	No of Samples	Cv. [1-9 rating]	No of Samples
Pearl [5]	7	Aquarelle	1	Haka [7]	1
Carat [7]	2	Camion [8]	1	Colossus [7]	1
Siberia [5]	2	Antonia	1	Jewel [7]	1
Flagon [6]	2	Cannock [8]	1	Sequel [7]	1
Rattle	2	Scylla [8]	1	Nocturne	1
Spectrum [6]	2	Pastoral [7]	1	Saffron [8]	1
Regina [5]	2	Vertige	1	Kingston	1

Table 2 Geographic origins of 2004 net blotch samples

County of origin	No of samples	County of origin	No of samples	County of origin	No of Samples
Cambs	19	Worcs	1	Devon	1
Suffolk	3	Herts	1	S. Yorks	1
Cornwall	2	Somerset	1	Norfolk	1
Beds	1	Lincs	1	Unknown	1

METHODS

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, some outmoded cvs and the winter cvs from the set of seedling differentials. Two replicates of each cv. were sprayed with mixed inoculum made up from all isolate samples received during the season. Inoculated plants were placed in dew chambers in the dark at 15ºC for 24 hrs. They were then placed in the glasshouse at approximately 15ºC 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 3)

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 three of the differential cvs, CI 739, Proctor and CI 9518. Based on the differential code numbers (Table 3) the isolate mixture carried virulence factors 4, 9 and 11. Virulence to these has been at a high frequency in the population for several years.
As adult plants, cvs expressed a range of quantitative responses with several showing good levels of resistance. Cultivar rankings generally confirmed their 1-9 disease ratings although Carat, Cannock and Colossus were perhaps relatively more heavily infected than might be expected from their ratings. Cv. Carat was also among the most susceptible cvs in 2003 tests. Cv. Regina was, as in 2003, relatively less heavily infected than would be expected from its disease rating of 5. When it was first included in tests in 1995 cv Regina had a disease rating of 9 (resistant) but virulence increased and by 2002, when it was the most susceptible cv. in glasshouse tests, its rating had fallen to 5. This suggests that cv. Regina may have a race specific resistance, which is only overcome when isolates carry the matching virulence factor(s). This may have been lacking in 2004 samples.
Seedlings of cv. Sequel were resistant, as they were in the previous three years when exposed to different isolate mixtures. It was also resistant as an adult plant although in 2002 it was adult plant susceptible. As in 2003, seedlings of cvs Amarena and Colossus were resistant; however as an adult plant, cv. Colossus was susceptible in 2004. Although these cvs consistently express seedling resistance their adult plant responses appear to fluctuate between years. Previously, the outmoded cv. Angela, behaved similarly. It appears from the seedling reactions of these cvs that they carry race specific resistance(s) the matching virulence(s) to which has not been identified in the pathogen. However the variations in the adult plant responses of some of these cvs between years are difficult to explain.
Of the potential new cvs included in seedling tests Surtees, Colibri and Boost were resistant.

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Table 3 *Percentage flag leaf area infected and seedling reaction types of winter barley cultivars to a mixture of net blotch isolates in glasshouse tests

Cultivar [1-9 rating]	Differential Code number	Flat leaf % infection	Seedling reaction	Cultivar	Differential code number	Seedling reaction
Carat [7]		18	S	CPBT B68		S
Pearl [5]		15	S	NSL 00-6692		S
Siberia [5]		15	-	Fahrenheit		S
Rattle		13	S	Nord.99565/17		S
Colossus [7]		13	R	CPBT B70		S
Cannock [8]		10	S	Surtees		R
Spectrum [6]		8	S	Colibri		R
Regina [5]		8	S	Boost		R
Haka [7]		8	S			
Pict [6]		6	S			
Aquarelle		6	S	CI 5401	1	R
Nocturne		4	S	CI 6311	2	R
Kingston		4	S	CI 9820	3	R
Amarena [8]		2	R	CI 739	4	S
Camion		1	S	CI 1243	5	R
Saffron [8]		1	S	CI 4795	6	R
Flagon [6]		1	S	CI 4502	7	R
Sequel [7]		0	R	CI 4979	8	R
Scylla [8]		1	S	Proctor	9	S
				CI 9214	13	R
Code 65	10	1	R			
CI 9518	11	20	S			
Tenn.61-119	12	1	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)