

UKCPVS 2006 ANNUAL REPORT

MILDEW OF WHEAT

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Virulence for Robigus, first detected in 2005, remained at an intermediate level in 2006.

Virulence was detected for the first time for the cultivar Timber.

Virulence for the commonly deployed resistance genes *Pm2*, *Pm4b*, *Pm6* and *Pm8* remained at, or close to, 100%.

Hyperion probably carries the resistance gene *Mld*. A number of provisional new R factor identifications were made for cultivars on the Recommended List.

INTRODUCTION

2006 was an unusually low mildew year. Although mildew infection was widely present in wheat growing areas throughout the UK, levels were generally very low.

160 mildew isolates were tested from 25 different wheat cultivars (Table1). 68 of the isolates came from the universally susceptible cultivar Cerco, exposed in mobile seedling traps in order to supplement the low number of mildew samples received from trials and crops.

Isolates tested came from 9 counties from across the UK, including N. Ireland (Table 2). Just over half were from East Anglia, due largely to the deployment of the mobile seedling traps in this region. There were no samples from Scotland.

Table 1. Cultivars from which mildew isolates were tested

Cultivar	Rgenes / factors	1-9 rating	% UK wheat area 2006	No. isolates tested
Alchemy	<i>(Pm2, Pm4b)</i>	7	4.0	6
Amaretto	Unknown	-	0.0	2
Ashby	Unknown	(7)	<0.1	2
Brompton	<i>Pm8</i>	4	1.4	2
Cerco	0	-	0.0	68
Challenger	Unknown	⁺ 6	0.0	4
Claire	<i>Pm2, Pm4b</i>	4	8.8	12
Consort	<i>Pm2, Pm4b, Pm6</i>	6	5.1	2
Cordiale	<i>Mld</i>	6	3.1	3
Granary	Unknown	⁺ 7	0.0	2
CPBT W141	Unknown	^{\$} (9)	0.0	2
CPBT W142	Unknown	^{\$} (8)	0.0	2
Gatsby	Unknown	7	0.1	7
Glasgow	Unknown	7	1.3	5
Haven	<i>Pm8</i>	6	0.0	2
Hobbit	0	2	0.0	2
Humber	<i>(Pm8)</i>	5	0.0	3
Maris Ranger	0	5	0.0	2
Robigus	Unknown	7	18.8	10
Sahara	Unknown	⁺ 6	0.0	2
Solstice	0	4	8.9	4
Timber	Unknown	9	0.0	8
Vuka	Unknown	-	0.0	2
Xi19	<i>MLAx</i>	7	2.7	4
ZE-99Z 531-14	Unknown	^{\$} (9)	0.0	2

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() Limited data

⁺ NL2 data^{\$} NL1 data

Table 2. Locations from which mildew isolates were tested

Region	County	No. of isolates tested
East Anglia	Cambridgeshire	30
	Suffolk	57
South East	Bedfordshire	8
	Hampshire	4
West Midlands	Herefordshire	2
	Shropshire	18
	Warwickshire	12
North of England	Yorkshire	17
Northern Ireland	CountyDown	12
TOTAL		160

METHODS

Isolates were inoculated onto detached leaf segments of differential cultivars using a spore settling tower. Inoculated leaf segments were incubated at 18°C with an 18 hour light / 6 hour dark regime. After 10-12 days, reaction types were assessed according to the method of Moseman *et al* (1965).

The standard set of differential cultivars, together with additional cultivars of UK relevance, are shown in Table 3.

Table 3. Differential cultivars used in 2006

Differential Cultivar	Resistance Factors (European codes)	Gene designations
<u>Standard set</u>		
Cerco	0	0
Galahad	Pm2	<i>Pm2</i>
Chul	Pm3b	<i>Pm3b</i>
Armada	Pm4b	<i>Pm4b</i>
Flanders	Pm5	<i>Pm5</i>
Brimstone	Pm6	<i>Pm6</i>
Clement	Pm8	<i>Pm8</i>
Maris Dove	Mld	<i>Mld</i>
Brock	Pm2,MITa2	<i>Pm2,MITa2</i>
Mercia	Pm5,MITa2	<i>Pm5,MITa2</i>
Tonic	MITo	<i>Pm3d+?</i>
Broom	Pm3d	<i>Pm3d</i>
Sicco	Pm5,MlSi2	<i>Pm5,MlSi2</i>
Wembley	MlSo	<i>MlSo</i>
Axona	MlAx	<i>MlAx</i>
Amigo	Pm17	<i>Pm17</i>
Shamrock	?	?
<u>Additional cultivars</u>		
Alchemy		
Gatsby		
Glasgow		
Hyperion		
Mascot		
Robigus		
Timber		

RESULTS AND DISCUSSION

Virulence frequencies in 2006 (Table 4) remained broadly similar to those in recent years.

Virulence for *Pm2*, *Pm4b*, *Pm5*, *Pm6*, *Pm8* and *MITa* were at, or near, 100%. Virulence for Alchemy and Mascot was similarly high, indicating that they probably carry one or more of these resistances.

Intermediate levels of virulence (20%-50%) were detected for *Mld*, *Pm3d* and *MlAx*, along with the cultivars Hyperion, Glasgow, Robigus and Gatsby. Hyperion reacted in a similar way to the *Mld* differential, Maris Dove, suggesting that Hyperion possesses *Mld*. There was also an indication that Robigus and Glasgow, although differing from one another, may have a component of their resistance in common.

In contrast to the situation in 2005, when virulence for Robigus was restricted to isolates collected from Robigus itself, this virulence was detected in isolates from a wide range of varieties in 2006.

This implies that virulence for Robigus is becoming more generally established in the mildew population.

Low levels of virulence (10% or less) were found for *Pm3b*, *Pm17*, Sicco, Wembley, Shamrock and Timber. This is the first time that virulence for Timber has been confirmed and it seems that this cultivar has a novel resistance which is unrelated to that of any other cultivar tested.

Table 4. Virulence frequencies 1997 - 2006

Virulence for	Frequency of virulence									
	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
<i>Pm2</i>	100	100	100	100	100	99	100	100	99	100
<i>Pm3b</i>	4	1	2	1	4	6	7	4	25	10
<i>Pm4b</i>	98	100	99	99	100	100	100	100	97	99
<i>Pm5</i>	95	88	91	88	90	89	92	90	92	95
<i>Pm2,Pm6</i>	99	100	100	99	100	100	100	99	97	98
<i>Pm8</i>	98	97	99	97	98	98	94	98	90	98
<i>Pm17</i>	16	8	22	2	9	13	4	6	11	9
<i>Mld</i>	26	18	6	12	25	24	18	18	30	31
<i>MITa2</i>	93	86	97	96	95	99	96	97	97	98
<i>MITo</i>	29	16	16	5	24	20	20	20	27	36
<i>MIbr</i>	30	16	15	8	24	27	20	21	30	37
<i>Pm5,MISi2</i>	21	17	20	8	8	15	6	6	20	9
<i>MISo</i>	15	10	6	4	6	11	4	4	16	10
<i>MIax</i>	20	7	1	1	10	8	8	9	13	23
<i>MISs</i>		65	57	74	82	93	90	86	98	
<i>MISh</i>			3	0	4	16	8	1	5	1
Alchemy										99
Gatsby										38
Glasgow										44
Hyperion										32
Mascot										94
Robigus									46	27
Timber										7
No. isolates tested	313	328	187	148	286	165	209	376	219	160

Table 5 shows the Recommended List winter wheat cultivars for 2007/08, grouped according to their resistance factors and the frequency of corresponding virulence in the mildew population.

Table 5. RL winter wheat cultivars for 2007/2008 – mildew resistance factors and frequency of corresponding virulence in 2006

Corresponding virulence frequency	Putative R Factors	Cultivar	Resistance Rating** (1-9)
High (>90%)	None	Hereward	6
		Solstice	4
	<i>Pm2, Pm4b</i>	Claire	4
		Istabraq	5
		<i>Alchemy</i>	7
		<i>Zebedee</i>	6
	<i>Pm2, Pm4b, Pm6</i>	Consort	6
		Deben	6
		Malacca	6
		Nijinsky	6
		Riband	6
		Richmond	5
		<i>Mascot</i>	6
	<i>Pm2, Pm4b, Pm6, Pm8</i>	Access	7
		Gladiator	6
		Napier	6
	<i>Pm8</i>	Ambrosia	6
		Brompton	4
		Welford	6
		<i>Humber</i>	5
<i>Pm2+</i>	Einstein	6	
<i>MISS</i>	Soissons	6	
Intermediate (20% - 45%)	<i>Mld</i>	Cordiale	6
		Hyperion	6
		<i>Battalion</i>	7
	<i>MIAx</i>	Xi19	7
	Unknown	Gatsby	7
		Glasgow*	7
		Robigus*	7
<i>Oakley*</i>		7	
Low (<10%)	Unknown	<i>Timber</i>	9

Cultivars in italics are provisional identifications.

* these cultivars may have some element of their specific resistance in common

** HGCA Recommended List winter wheat

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UKCPVS 2006 ANNUAL REPORT

YELLOW RUST OF WHEAT

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Virulence frequencies in 2006 were similar to 2005, with high levels of WYV 4, WYV 9, WYV 17, WYV CV and virulence for Robigus and a low level of WYV 6.

There was no evidence of virulence for Claire.

There were indications that two isolates from the 2006 survey may carry combined virulence for WYR 6 and Robigus.

An isolate from the 2005 survey produced moderate levels of infection on Timber in adult plant tests. This cultivar has previously been completely resistant, with an HGCA resistance rating of 9.

Many new and established cultivars were resistant to all isolates.

INTRODUCTION

The incidence of yellow rust in 2006 was low, with the disease being limited mainly to the high risk areas of eastern England and the east of Scotland.

The cultivars from which isolates were tested are shown in (Table 1). The most common source cultivar was the popular yellow rust susceptible cultivar Robigus, which occupied an estimated 18.8% of the UK wheat area in 2006.

The locations from which isolates were tested are shown in Table 2. The majority of isolates were from East Anglia, predominantly Cambridgeshire. These included 5 isolates from inoculated disease trials.

SEEDLING VIRULENCE TESTS OF ISOLATES COLLECTED IN 2006

METHODS

27 isolates were selected for testing on the basis of their source cultivar and location.

Virulence tests were carried out on seedlings of the differential cultivars listed in Table 3, using the methods described by Priestley, Bayles and Thomas, 1984. Additional cultivars, of particular relevance to UK breeding, were included in the differential set.

Table 1. Cultivars from which yellow rust isolates were tested

Cultivar	WYR factors	1-9 resistance rating*	% UK wheat area 2006#	No. of isolates tested
<u>RL varieties</u>				
Robigus	Rob	3	18.8	12
Glasgow	0	4	1.3	3
Napier	6,9,17	4	1.8	1
<u>RL Candidates</u>				
Timber	?	9†	0.0	2
Oakley	6,9,17?	6	0.0	1
<u>Other cultivars</u>				
Vuka	0	-	-	4
Victo	0	-	-	2
Hornet	6,9	-	-	1
Slejpner	9	-	-	1
TOTAL				27

*HGCA resistance ratings for 2007/08.

†Isolates of yellow rust which can infect Timber were found in the UK in 2006, but they are very uncommon.

From UK seed production statistics – weights of seed certified harvest 2005.

Table 2. Locations from which yellow rust isolates were tested

Region	County	No. of isolates tested
East Anglia	Cambridgeshire	12
	Norfolk	1
	Suffolk	5
South East	Essex	3
	Hants	1
North East	Durham	2
	Northumberland	1
Scotland	Perthshire	2
TOTAL		27

Table 3. Differential cultivars used in 2006 seedling virulence tests.

Differential cultivar	WYR factor	Gene designation
<u>Core set</u>		
Hybrid 46	WYR 4	<i>Yr4</i>
Heines Kolben	WYR 2,6	<i>Yr2, Yr6</i>
Heines Peko	WYR 2,6	<i>Yr2, Yr6</i>
Lee	WYR 7	<i>Yr7</i>
Brock	WYR 7	<i>Yr7</i>
Compair	WYR 8	<i>Yr8</i>
Kavkaz x 4 Fed	WYR 9	<i>Yr9</i>
Clement	WYR 9	<i>Yr9</i>
AVS xYr 15	WYR 15	<i>Yr15</i>
VPM 1	WYR 17	<i>Yr17</i>
Carstens V	WYR CV	<i>Yr32</i>
<u>Additional cvs</u>		
Reaper	WYR 17	
Talon	WYR CV	
Robigus	WYR Rob	
Oxbow	WYR Oxb	
Madrigal	WYR 6,9,17	
Einstein	WYR 6?	
Claire	Rx	
Buster	R	
Cadenza	R	
Hornet	WYR 6,9	
Mascot	WYR 6,17	
Timber	WYR ?	

RESULTS and DISCUSSION

A reduced core set of differential cultivars was used in 2006, omitting WYR 1, WYR 2, WYR 3, WYR 10 and WYR Sp (Table 3). The list of additional cultivars was updated to include Timber, a new RL cultivar previously resistant to all isolates, Hornet WYR 6,9 and Mascot WYR 6,17.

Virulence frequency data for 2006, together with data from 1997-2005 (Bayles *et al*, 2005) are shown in Table 4.

As in 2005, there was a very high frequency of virulence for WYR 4, WYR 9, WYR CV and for Robigus and Oxbow.

Virulence for WYR 6, and for cultivars carrying WYR 6 in combination with other resistance factors, remained at a low frequency. Since all but one of the isolates carrying WYV 6 was derived from inoculated trial plots, frequency in the population as a whole is probably even lower than indicated by this result.

Two isolates were virulent on Timber, a new cultivar which has been resistant to all isolates to date and has an HGCA resistance rating of 9.

There was no evidence of virulence for Claire in any of the isolates tested in 2006, despite some indications of virulence in 2005 tests. No virulence was detected for the differentials for WYR 8 or WYR 15 nor for the additional cultivars Buster or Cadenza

Table 5 shows pathotype frequencies in 2006, compared with their 2004-2005 values. As in 2005, by far the most common pathotype was one combining the virulences WYV 4,9,17,CV and virulence for Robigus and Oxbow.

Two isolates (7%) appeared to combine virulence for WYR 6 with virulence for Robigus. These also gave intermediate to susceptible reaction types on Timber. One of these isolates will be examined further in 2007 adult plant tests.

Table 4. % Virulence frequencies from 1997 to 2006.

Virulence for	97	98	99	00	01	02	03	04	05	06
WYR 1	100	99	99	100	100	97	100	100	100	-
WYR 2	100	99	99	100	100	97	100	100	100	-
WYR 3	100	100	100	100	100	97	100	93	100	-
WYR 4	47	79	87	90	74	63	86	50	87	100
WYR 6	1	7	21	32	39	31	50	42	10	19
WYR 7	7	4	10	4	0	3	36	4	8	11
WYR 8	0	0	0	0	0	0	0	0	0	0
WYR 9	99	99	99	92	90	88	93	100	95	100
WYR 15					0	0	0	0	0	0
WYR 17	99	99	100	96	77	88	93	85	97	100
WYR CV	13	1	4	16	42	73	64	38	85	89
WYR Sp		0	0	0	0	0	7	0	0	-
<u>Additional cvs</u>										
Reaper	17									100
Talon	CV									85
Robigus	Rob							31	79	89
Oxbow	Oxb			16	32	50	50	31	82	85
Claire	Rx								23	0
Madrigal	6,9,17								8	11
Einstein	6								5	11
Buster*	R	0	0	0	0	0	7	0	0	0
Cadenza	R				0	0	0	0	0	0
Hornet	6,9									19
Mascot	6,17									11
Timber	?									7
No. of isolates tested	138	94	97	50	31	36	14	48	39	27

* or Parade (believed to have the same resistance)

- not included in test

Table 5. Frequency (%) of pathotypes detected in 2006, with their 2004-05 values (omitting WYV1, WYV2 and WYV3)

Pathotype (WYV)	2004	2005	2006
4,9,17,CV,Rob	19	74	74
4,7,9,17,CV,Rob	2	0	7
4,6,9,17,CV,Rob*	0	5	4
4,6,9,17,CV	2	0	4
4,6,9,17,Rob*	0	0	4
4,6,7,9,17	0	3	4
4,6,9,17	23	0	4

* also virulent on Timber

ADULT PLANT TESTS

METHODS

7 isolates (Table 7) were tested on a set of 49 cultivars in adult plant tests in field isolation nurseries. Seedling tests of the same isolates and cultivars were carried out under standard controlled environment conditions.

Table 7. Isolates tested on adult plant in 2006.

Code	Year	Location	Cultivar	Virulence
03/515	2003	Cambs	Goodwood	1,2,3,4,6,7,9,17,CV
04/37	2004	Cambs	Defender	1,2,3,4,6,(7),9,17,(CV),Rob
05/1	2005	Cambs	Consort	1,2,3,4,7
05/31	2005	Lincs	Robigus	1,2,3,4,6,9,17,(CV),Rob
05/34	2005	Norfolk	Brigadier	1,2,3,9,17
05/501	2005	Cambs	Gladiator	1,2,3,6,9,17
05/503	2005	Cambs	Brompton	1,2,3,4,6,7,9,17

RESULTS AND DISCUSSION

The results of adult plant tests are given in Table 8.

Table 8. Adult plant field tests. Percentage leaf area infected with yellow rust (mean of 3 assessments)

Cultivar	WYR Factors	Isolate code and WYV factors						
		05/1 1,2,3,4,7	05/34 1,2,3,9,17	05/501 1,2,3,6,9,17	05/503 1,2,3,4,6,7,9,17	03/515 1,2,3,4,6,(7),9,17,CV	04/37 1,2,3,4,6,(7),9,17 (CV)	05/31 1,2,3,4,6,9,17, (CV)Ro,Ox
Talon	CV	13.7	0.2	0.2	32.2	33.3	19.2	33.0
Hereward	CV+	3.8	0.0	0.0	2.4	10.2	1.5	0.9
Consort	CV+	0.0	0.0	0.2	0.0	0.2	0.1	12.8
Oxbow	CV+	4.2	0.4	10.5	4.0	11.0	4.1	15.7
Robigus	CV+	0.2	1.4	8.0	1.8	4.4	7.0	21.0
Battalion	CV+	0.1	0.0	1.7	0.8	0.0	7.0	8.2
Hyperion	6,(9),17	0.4	0.5	9.7	8.5	5.0	10.5	12.0
Mascot	6,17	1.6	1.0	13.7	13.3	9.8	21.3	16.7
Napier	6,9,17	4.2	1.2	11.3	12.5	6.9	12.0	15.2
Oakley	6,(9),17	2.4	0.5	9.5	8.9	4.5	10.0	13.5
Hornet	6,9	2.4	0.2	12.7	11.7	11.2	21.3	33.7
Einstein	6+	2.4	0.0	2.1	0.9	8.8	0.6	1.4
Brigadier	9,17	11.9	32.5	34.5	24.5	19.7	32.8	33.5
Reaper	17	1.7	14.2	13.7	13.7	12.5	19.7	24.8
Clement	9	3.4	20.0	17.5	10.8	10.5	25.2	28.5
Slejpner	9	1.2	20.8	24.3	14.8	9.9	17.3	20.0
Stetson	1,9	1.5	16.0	16.0	11.3	8.3	7.9	17.5
Brock	7,14	10.0	0.9	2.2	5.0	7.2	5.8	0.0
Cordiale	7	8.3	1.2	0.1	5.2	6.9	0.6	0.0
M. Huntsman	13	0.6	7.4	5.2	3.4	0.4	7.4	10.7
Hobbit	14	10.2	13.0	10.5	9.2	17.5	12.0	13.2
Glasgow	?0	8.2	0.2	8.5	7.3	6.5	10.0	9.7
Vuka	0	10.2	11.8	11.5	12.5	17.8	15.5	16.0
AC Barrie	0	39.5	25.0	39.2	38.7	47.8	37.3	46.5

Yellow highlighting = elevated infection levels, indicating compatible variety x isolate interactions at the adult plant stage.

Grey highlighting = low / intermediate infection levels which, although they be the result of compatible variety x isolate interactions, are more likely to have arisen due to contamination from other isolates.

Green highlighting = nil or very low infection, indicating incompatibility.

Table 8 contd. Adult plant field tests. Percentage leaf area infected with yellow rust (mean of 3 assessments)

Cultivar	WYR Factors	Isolate code and WYV factors						
		05/1	05/34	05/501	05/503	03/515	04/37	05/31
		1,2,3,4,7	1,2,3,9,17	1,2,3,6,9,17	1,2,3,4,6,7,9,17	1,2,3,4,6,(7),9,17,CV	1,2,3,4,6,(7),9,17 (CV)	1,2,3,4,6,9,17, (CV)Ro,Ox
Benedict	R	0.0	0.0	0.0	0.0	0.0	0.0	2.1
Timber	R?	0.0	0.0	0.0	0.0	0.0	0.0	11.8
Dover	R	0.0	0.1	0.2	0.0	0.0	0.0	1.6
Alchemy	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Boston	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Brompton	R	0.0	0.0	0.0	0.0	0.0	0.0	0.4
Buster	R	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Cadenza	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Claire	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Contender	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Deben	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gatsby	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gladiator	R	0.0	0.2	0.1	0.0	0.0	0.0	0.2
Gulliver	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Humber	R	0.0	0.0	0.0	0.1	0.0	0.0	0.0
Istabraq	R	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Kipling	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Malacca	R	0.0	0.0	0.1	0.0	0.0	0.0	0.0
Nijinsky	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Ochre	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sahara	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solstice	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tara	R	0.3	0.0	0.0	0.0	0.0	0.0	0.0
Xi19	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Zebedee	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Glasgow	?0	8.2	0.2	8.5	7.3	6.5	10.0	9.7
Vuka	0	10.2	11.8	11.5	12.5	17.8	15.5	16.0
AC barrie	0	39.5	25.0	39.2	38.7	47.8	37.3	46.5

Yellow highlighting = elevated infection levels, indicating compatible variety x isolate interactions at the adult plant stage.

Grey highlighting = low / intermediate infection levels, which, although they may indicate compatible variety x isolate interactions are more likely to be the result of contamination from other isolates.

Green highlighting = nil or very low infection, indicating incompatibility

Isolates

Isolates 05/1, 05/34 and 05/501 represent pathotypes which are now uncommon in the UK yellow rust population. Their virulence in adult plant tests largely confirmed expectations from seedling reactions. An exception was the high levels of infection seen on Robigus and Oxbow in the test inoculated with 05/501. It seems likely that this was due to infection by incoming inoculum.

Isolate 05/503 was included in adult plant tests because of its apparent virulence for Claire in seedling tests. However, Claire proved to be completely resistant to this isolate at the adult plant stage.

The virulence of isolate 03/515 for Hereward and Einstein was evident for the third year running.

Isolate 04/37, which in 2005 adult plant tests appeared to give high levels of infection on Robigus and Oxbow as well as on the WYR 6,(9),17 cultivars Hyperion, Mascot and Napier, was less clearly virulent on Robigus / Oxbow in 2006. It seems that this isolate may not after all carry combined virulence for these two key groups of UK cultivars.

05/31, another isolate suspected of carrying this virulence combination, did appear to give high levels of infection on cultivars in both groups. However, the isolate is undergoing further tests because of discrepancies between seedling and adult plant reactions. 05/31 produced moderate levels of infection on Timber, a cultivar which has previously been completely resistant. Isolates have been taken from Timber for further testing on seedlings and adult plants.

Cultivars

Nearly half of the cultivars in test remained resistant to all isolates. The resistance of one cultivar, Timber appears to have been overcome by a new pathotype. The remaining cultivars, with the exception of the universally susceptible controls Vuka and AC Barrie, possess specific resistances which were effective against some isolates and ineffective against others.

Amongst recent additions to the HGCA Recommended List, Humber and Zebedee were resistant to all isolates, consistent with their high resistance ratings of 9. Oakley appeared most similar to the WYR 6, (9), 17 cultivars and Battalion to cultivars in the Robigus group. The resistance of Timber has yet to be identified, but it is clearly dissimilar to other varieties tested.

Seedling tests indicate that Einstein possess WYR 6. However, adult plant tests show that the cultivar it is not invariably susceptible to isolates possessing WYV 6, implying that it carries additional specific resistance, which may be of an adult plant type.

Glasgow is known to be susceptible to the vast majority of UK isolates, but there seem to be certain pathotypes to which it is resistant, indicating that it carries unidentified specific resistance. In the 2006 tests, Glasgow was resistant at seedling and adult stages to isolate 05/34. There is no obvious explanation for this and unidentified resistances / virulences are likely to be involved.

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BROWN RUST OF WHEAT

A L SKELLERN & R A BAYLES.

Virulence for the resistant cultivar Robigus was detected for the first time in 32% of isolates tested.

60% of isolates were virulent on the resistant cultivar Hyperion.

Virulence for *Lr10*, which has been used widely in UK varieties, was at a very high frequency.

Virulence for *Lr26*, also widely deployed, was at around 50%.

There was evidence that Glasgow possesses the specific resistance *Lr1*.

An isolate collected from Glasgow in 2005 gave high levels of infection on adult plants of the cultivar in a field test.

INTRODUCTION

Brown rust was not a widespread problem in 2006, although locally high levels developed on susceptible wheat varieties from late June onwards.

25 isolates were tested, from a total of 10 different wheat cultivars, including the resistant cultivars Robigus, Hyperion, Timber and Oakley (Table 1). Samples were also tested from the cultivars Benedict and Gladiator, which have high disease resistance ratings.

Table 1. Cultivars from which brown rust isolates were tested

Cultivar	R genes/factors	⁺ 1-9 rating	% UK wheat area 2006	No. isolates tested
Alchemy	*R Claire	4	3.9	4
Ambrosia	Lr 26 +	7	0.7	1
Claire	*R Claire	5	9.1	2
Benedict	?	8	0.0	1
Gladiator	Lr 26 +	8	5.9	1
Glasgow	Lr 1	5	1.3	4
Hyperion	?	9	0.2	2
Oakley	?	9	0.0	1
Robigus	?	9	17.6	8
Timber	?	9	0.0	1
TOTAL				25

* believed to be similar to Claire

⁺HGCA Recommended List for 2007/2008

Table 2 shows the locations from which the samples were collected. The majority were from the east of England, and in particular from East Anglia. The most northerly sample was from Yorkshire.

Table 2. Locations from which brown rust isolates were tested

Region	County	No. isolates tested
East Anglia	Cambridgeshire	14
	Norfolk	4
South East	Hampshire	2
	Kent	3
East Midlands	Lincolnshire	1
North East	Yorkshire	1
TOTAL		25

METHODS

Isolates of *Puccinia triticina* were cultured from the samples received and 25 were selected for virulence testing on the basis of their source cultivar and location. Isolates were tested for virulence on seedlings of three sets of wheat lines: 1) the standard WBR differential cultivars, 2) the core set of ‘Thatcher’ Near Isogenic Lines (NILS) carrying different *Lr* resistance genes, and 3) current cultivars with known or unknown resistance genes (Table 3).

Seedlings of the differential cultivars were grown in a spore-proof glasshouse and inoculated at the first leaf stage with a spore: talc mixture, using a rotary inoculator. Inoculated seedlings were placed in a sealed polythene bag in a refrigerator at 5°C for 48 hours in the dark. They were then transferred to a controlled environment growth room where they were maintained at a constant temperature of 20°C (12 hour photoperiod) for 12-14 days, after which they were assessed for reaction type.

Table 3. Differential cultivars used in 2006 seedling virulence tests

Differential cultivar	WBR factor	Lr gene
<u>Standard WBR cultivars</u>		
Clement	WBR 1	<i>Lr26</i>
Fundin	WBR 2	<i>Lr17b</i>
Sappo	WBR 3	<i>Lr20</i>
Halberd	WBR 4	<i>Lr20</i>
Sterna	WBR 7	<i>Lr3a</i>
Armada	WBR 0	
<u>Thatcher near isogenic lines</u>		
Tc*6/Centenario		<i>Lr1</i>
Tc*6/Exchange		<i>Lr10</i>
Tc*6/Frontana		<i>Lr13</i>
Tc*6/ST-1.25		<i>Lr26</i>
Tc*8/VPM1		<i>Lr37</i>
Thatcher		<i>Tc</i>
<u>Additional cultivars</u>		
Consort		<i>Lr10, Lr13</i>
Napier		<i>Lr10, Lr26, Lr37</i>
Savannah		<i>Lr26, Lr37</i>
Glasgow		<i>Lr1</i>
Claire		?
Alchemy		?
Robigus		?
Hyperion		?

RESULTS AND DISCUSSION

Seedling virulence frequencies are shown in Table 4.

All isolates were virulent at the seedling stage on differentials carrying adult plant type resistances (*Lr13*, *Lr37*, 'Claire') and on the temperature sensitive resistance of Maris Fundin (WBR 2).

There was also an extremely high frequency of virulence for *Lr10*, the resistance found, in combination with *Lr13*, in Consort.

Virulence for WBR 7 and for the unidentified resistance in Hyperion were both detected in more than 60% of isolates.

Virulence for WBR 1 / *Lr 26*, WBR 3, WBR 4, Glasgow and Robigus was detected at moderate frequencies, in 24%-44% of isolates. This is the first time that virulence has been confirmed for Robigus.

Further analysis of the data confirmed previous indications that Glasgow possesses the resistance *Lr1*.

Table 4. Virulence frequencies 1998-2006.

Virulence For	% Frequency[†]								
	1998	1999	2000	2001	2002	2003	2005	2006	
WBR cvs									
Clement	WBR 1	43	27	82	100	84	73	69	44
Fundin	WBR 2	75	32	60	94	56	73	100	100
Sappo	WBR 3	0	0	8	0	0	0	13	28
Halberd	WBR 4	0	0	4	0	0	0	13	24
Sterna	WBR 7	7	7	61	65	50	68	56	68
Armada	WBR 0	100	100	100	100	100	100	100	100
Thatcher NILS									
Tc6/Centenario 1	Lr1	0	0	0	0	0	0	28	32
Tc*6/Exchange	Lr10								96
Tc*6/Frontana	Lr13								100
Tc6/ST-1.25	Lr26	43	32	83	100	73	73	69	44
Tc*8/VPM1	Lr37								100
Thatcher	0	-	-	-	100	100	100	100	100
Additional cultivars									
Consort	Lr10, Lr13								96
Napier	(Lr10, Lr26, Lr37)								36
Savannah	Lr26, Lr37								40
Glasgow	(Lr1)								32
Claire	R Claire								100
Alchemy	R Claire								100
Robigus	?								32
Hyperion	?								60
Number of isolates tested		43	22	23	17	14	22	32	25

[†]Isolate numbers tested in 2004 were small and the data have been excluded.

ADULT PLANT TESTS

METHODS

49 wheat cultivars, including those on the HGCA Recommended List of winter wheat varieties, potential new cultivars, outmoded cultivars and standard differentials were sown in two nurseries. The nurseries were inoculated with one of two isolates from the 2005 survey (Table 5). One isolate had been collected from a severe infection on Claire and the other from a severe infection on Glasgow.

Plants were assessed once on 30 June for percentage leaf area infected.

Table 5: Isolates tested in adult plant field tests 2006

Code	Year	Location	Cultivar	Virulence
05-35	2005	Kent	Claire	WBV 1,2,3,4,7
05-78	2005	Lincoln	Glasgow	WBV 2

RESULTS AND DISCUSSION

The results of adult plant tests are shown in Table 6.

The two isolates produced moderately high levels of infection on susceptible cultivars. Both were virulent on the adult plant resistances WBR 5 (*Lr 13*) and WBR 9, on the temperature sensitive resistance WBR 2 and on *Lr10*. In addition, 05-78 was virulent on WBR1 (*Lr26*) and on WBR 7 (*Lr 3a+*).

Contrary to expectations, 05-35, from a heavily infected plot of Claire, showed no evidence of virulence for Claire or the related cultivars Alchemy and Zebedee. This isolate will undergo further testing to establish whether lack of virulence might have been an environmental effect peculiar to the site and season in which the test was carried out.

05-78, from Glasgow, was clearly virulent on this cultivar at the adult plant stage and also on the cultivar Benedict. The implication is that Benedict, like Glasgow, possesses the resistance *Lr1*, which, although not widely deployed to date in UK cultivars, has been used in most wheat growing areas. Corresponding virulence is therefore common worldwide, rendering the resistance largely ineffective if it is deployed alone.

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Table 6 . Adult plant field tests. Percentage leaf area infected with brown rust (30 June)

Cultivar	WBR	Lr	Isolate code	
			05-35	05-78
Clement	1	26	20	2
Fundin	2	17b	30	5
Huntsman	5	13	32	22
Gamin	6		4	2
Sterna	7	3a+	4	Trace
Ranger	8		Trace	Trace
Avalon	9		32	20
Alchemy			0.3	0.6
Ambrosia		26+	1	2
Battalion			Trace	Trace
Claire			1	Trace
Dover			0	0.1
Gulliver			Trace	0.3
Hyperion			0.1	0.7
Istabraq			1	1
Nijinsky			0.1	1
Oakley			0	0
Richmond			Trace	0.7
Robigus			Trace	0
Sahara			0.4	2
Timber			0	0
Zebedee			1	3
Malacca		10,13(37?)	3	7
Xi19			4	5
Armada		0	7	10
Deben			7	8
Solstice			8	10
Einstein		(10)	11	12
Hereward		10,13	12	12
Smuggler			13	9
Mascot			22	13
Ochre			27	20
Cordiale			28	13
Consort		10,13	30	28
Dickson			30	22
Riband		13,17b	30	25
Gladiator		26+	8	4
Access		(10,26,37)	8	1
Napier		(10,26,37)	5	2
Brompton		26	20	1
Challenger			23	3
Gatsby		26+	12	0.8
Humber			25	0.1
Kipling		26	27	1
Soissons		14a	28	0.4
Tanker		26+	30	2
Welford		26 (10,37)	28	3
Benedict		1?	0.1	15
Glasgow		1	2	28

Tan highlighting = elevated infection levels, indicating compatible variety x isolate interactions at the adult plant stage.

Green highlighting = nil or very low infection, indicating incompatibility.

Grey highlighting = uncertain

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BROWN RUST OF BARLEY

A J HUBBARD and R A BAYLES

Virulence corresponding to nine of the ten barley brown rust resistance factors was detected at moderate to high frequency. BBR 7 remained effective against all isolates.

A diverse range of complex pathotypes were identified.

Isolates were tested from two spring barley cultivars, Waggon and NFC Tipple, which have high resistance ratings of 8. These cultivars appear to carry BBR 3, which is matched by around 30% of isolates.

INTRODUCTION

22 isolates were tested, 11 from winter cultivars and 11 from spring cultivars (Table1). These included isolates from the relatively resistant spring cultivars NFC Tipple and Waggon, both of which have ratings of 8.

Table 2 shows the locations from isolates were received. The majority of samples were from Cambridgeshire, but others were from widely dispersed locations, including Scotland, Wales and N.Ireland.

SEEDLING VIRULENCE TESTS OF ISOLATES COLLECTED IN 2006

METHODS

Isolates were tested on a core set of differential cultivars. Additional cultivars, of particular relevance to UK breeding, were also included (Table 3).

Seedlings were grown in pots in a spore-proofed glasshouse. Following inoculation, sealed plastic domes were placed on the pots, which were incubated in the dark at 6 °C for 48 hours. Tests were then grown in controlled environment rooms with a light and temperature regime of 16 hours light at 18 °C and 8 hours dark at 11 °C for approximately 14 days. Reaction types were assessed using a standard 0-4 scale.

Table 1. Cultivars from which brown rust isolates were tested

Cultivar	1-9 resistance rating*	% UK barley* area 2006#	No. of isolates tested
<u>RL winter cultivars</u>			
Boost	4	0.01	6
Cannock	5	0.7	1
Colibri	7	0.6	1
Sequel	6	9.8	1
Pict	7	2.9	1
<u>RL spring cultivars</u>			
Cellar	7	2.5	1
Chalice	4	1.0	1
Optic	5	27.4	1
Oxbridge	6	3.1	1
NFC Tipple	8	3.1	1
Static	7	4.7	1
Tocada	4	0.2	2
Waggon	8	1.9	2
Wicket	7	0.3	1
<u>Other winter cultivars</u>			
Marado	-	-	1
TOTAL			22

*HGCA resistance ratings for 2007/08.

From UK seed production statistics – weights of seed certified harvest 2005.

* winter cultivars as % winter barley area, spring cultivars as % spring barley area

Table 2. Locations from which isolates were tested.

Region	County	No. of samples tested
East Anglia	Cambridgeshire	10
	Norfolk	1
Yorkshire	N. Yorkshire	1
South East	Hampshire	3
South West	Dorset	1
Wales	Gwent	1
Scotland	Scotland	1
N.Ireland	County Down	4
TOTAL		22

Table 3. Differential cultivars used in 2006 seedling virulence tests.

Differential cultivar	BBR factor	Rph gene
<u>Core set</u>		
Sudan	1	<i>Rph1</i>
Peruvian	2	<i>Rph2</i>
Simon	3	<i>Rph3</i>
Gold	4	<i>Rph4</i>
Quinn	5	<i>Rph2,Rph5</i>
Bolivia	6	<i>Rph2,Rph6</i>
Cebada Cepa	7	<i>Rph7</i>
Egypt 4	8	<i>Rph8</i>
Hord. 2496	9	<i>Rph9</i>
Trumpf	10	<i>Rph12</i>
<u>Additional cvs</u>		
NFC Tipple	?3	
Waggon	?3	
Static	?3	
Cellar	?3	
Optic	10	

RESULTS

Virulence frequency data for 2006, together with data from 1997 -2005 (Jones, 2002, 2004 and 2005), are shown in Table 4.

Table 4. Virulence Frequencies from 1997 to 2006.

Virulence for	97	98	99	00	01	02	03	04	05	06
BBR 1	100	100	100	100	100	100	100	100	100	100
BBR 2	100	100	100	100	100	100	100	100	100	59
BBR 3	30	23	36	50	34	36	65	40	42	32
BBR 4	100	100	100	100	100	100	100	100	100	100
BBR 5	88	96	100	83	80	82	90	75	78	50
BBR 6	100	100	100	100	100	100	100	100	100	55
BBR 7	0	0	0	0	0	0	0	0	0	0
BBR 8	100	100	100	100	100	100	100	100	100	91
BBR 9	55	33	50	83	61	68	90	100	100	55
BBR 10	88	45	50	83	61	68	90	100	100	68
<u>Additional cultivars</u>										
NFC Tipple	?	3								27
Waggon	?	3								32
Static	?	3								36
Cellar	?	3								36
Optic	10									41
No. of isolates tested	33	27	14	6	41	33	29	20	26	22

Virulence for BBR 1 and BBR 4 was detected in all isolates, BBR 8 was also high occurring in 91% of isolates.

Virulence for BBR 2, 5, 6, 9 and 10 was detected in a moderate number of isolates, with virulence frequencies ranging from 50-68% of isolates.

32% of isolates showed virulence for BBR 3. A similar frequency of virulence was detected for the cultivars Waggon, NFC Tipple, Static and Cellar, which have all previously been reported as carrying BBR 3 (Jones, 2005).

As previously, no virulence was detected for BBR 7.

14 different pathotypes were identified in the 22 isolates tested (Table 5).

Table 5. Frequency (%) of pathotypes detected in 2006, with their 2004-05 values.
(Pathotype designation based on 'core set' differentials listed in Table 3).

Pathotype (BBV)	2004	2005	2006
1,2,3,4,5,6,8,9,10	30	30	9
1,2,3,4,6,8,9,10	10	12	5
1,2,4,5,6,8,9,10	-	-	14
1,2,4,6,8,9,10	15	10	5
1,2,4,8,9,10	-	-	5
1,4,6,8,9,10	-	-	5
1,2,3,4,9,10	-	-	5
1,2,4,5,6,8	-	-	14
1,3,4,8,10	-	-	9
1,2,4,9,10	-	-	5
1,4,5,6,8	-	-	9
1,4,8,10	-	-	5
1,4,5,8	-	-	5
1,4,8	-	-	5

ADULT PLANT TESTS

METHODS

A single winter barley adult plant nursery was conducted in 2006 at IGER, Aberystwyth. 32 varieties were sown including those on the HGCA Recommended List, the RL Candidates and some outdated cultivars of interest.

The nursery was artificially inoculated using spores of isolate BBR 03-25.

RESULTS

The majority of winter barley cultivars were highly susceptible in adult plant tests which are reflected in their disease resistance ratings of 6 or below. Colibri and Pict, both which have a rating of 7, also displayed high infection levels. Other varieties such as Pearl and Flagon [7] showed continuing good levels of partial resistance. Pelican and Amarena [8] remained resistant.

Table 6. Adult plant field tests. Percentage leaf area infected with brown rust

Cultivar * [1-9 rating]	% infection
Siberia [5]	42
Colossus [3]	38
Fahrenheit	30
Colibri [7]	30
Retriever [5]	30
Celebrity	28
Carat [4]	28
Camion [5]	27
Spectrum [5]	27
Marado	25
Pict [7]	25
Bronx [5]	22
Boost [4]	22
Cypress	22
Regina	22
Cannock [5]	21
Sequel [6]	20
Saffron	18
Dolphin	18
Scylla	17
Suzuka	14
Blythe	14
Cassata	13
Accent	12
Fanfare	12
Pearl [7]	12
Surtees	10
Shangrila	7
Flagon [7]	5
Monalisa	1
Pelican [8]	0.4
Amarena [8]	0.2

* HGCA Recommended List for 2007/08.

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