**MILDEW OF WHEAT**

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Mildew levels were higher in 2002 than in 2001 and 209 isolates were tested. There was little change in the composition of the population. The most common specific resistance genes are ineffective, being matched by high corresponding virulence frequencies, although effective partial resistance is commonly found. The new varieties Robigus (winter) and Tybalt (spring) appear to have effective uncharacterised specific resistance genes: both have ratings of 9. The new winter varieties Scorpion 25 and Wizard also have good mildew resistance. Shamrock is now the most susceptible variety; its rating having fallen to 2, despite a low virulence frequency of VSh.

## INTRODUCTION

Wheat mildew levels were higher in 2002 than 2001 (Clarkson & Slater, 2002). Infection occurred early in the autumn and disease carry-over was facilitated by a mild winter. By late winter, severe infection caused lower leaf death on susceptible varieties, *e.g.* Claire and Option, particularly in western and eastern England. Levels declined somewhat in the spring, due to both rain and lower leaf senescence, although occasional drier periods favoured development of new pustules on new growth of the susceptible varieties. By GS39, mildew levels were generally low in most areas, although more infection was present in western areas. Some late development occurred on susceptible varieties in eastern England.

## METHODS

158 samples were collected in 2002, mostly from winter cultivars. 208 single colony isolates were successfully recovered from 111 samples and tested. In addition, one bulk isolate taken from heavily infected plants of cv. Claire was tested. The source cultivars of the tested isolates are shown below:

| **Winter cultivars** | No. of isolates | | No. of isolates | | No. of isolates |
|---|---|---|---|---|---|
| Shamrock | 14 | Biscay | 6 | Macro | 4 |
| Option | 11 | Chardonnay | 6 | Arran | 4 |
| Claire | 10 | Savannah | 6 | Phlebas | 4 |
| Consort | 10 | Tanker | 6 | Scorpion 25 | 4 |
| Goodwood | 10 | Wizard | 6 | Soissons | 4 |
| Einstein | 10 | Richmond | 5 | Warlock 24 | 4 |
| Tellus | 9 | Access | 4 | Buchan | 2 |
| Hereward | 8 | Brunel | 4 | Riband | 2 |
| Malacca | 8 | Carlton | 4 | Xi19 | 2 |

| | | | | | |
|---|---|---|---|---|---|
| Equinox | 7 | Charger | 4 | Madrigal | 1 |
| Napier | 7 | Chatsworth | 4 | | |
| Solstice | 7 | Deben | 4 | Unknown cultivars | 3 |
| **Spring cultivars** | | | | | |
| Chablis | 2 | Paragon | 2 | Imp | 1 |
| **TOTAL** | | | | | **209** |

The samples were collected from the following locations:

| | No. of isolates | | No. of isolates |
|---|---|---|---|
| NIAB HQ, Cambridge | 72 | Peterborough, Cambs. | 2 |
| Waterbeach, Cambs. | 62 | Shrewsbury, Shropshire | 2 |
| Morley, Norfolk | 29 | Denbigh, Clwyd, Wales | 1 |
| Headley Hall, N Yorks. | 19 | Great Dunmow, Essex | 1 |
| Cockle Park, Northumb'd. | 9 | Mansfield, Notts. | 1 |
| Beckbury, Shropshire | 2 | Norwich, Norfolk | 1 |
| Callow, Herefordshire | 2 | Wimbish, Essex | 1 |
| Coleshill, Warks. | 2 | West Midlands | 1 |
| Cranwell, Lincs. | 2 | | |
| **Total** | | | **209** |

Isolates were inoculated onto detached leaf segments of differential cultivars using a spore settling tower and assessed according to the method of Moseman *et al*, 1965. The differential cultivars containing specific resistance genes/factors used to test for corresponding specific virulence genes/factors are shown in Table 1. The winter cultivars Einstein and Robigus and the spring cultivars Morph and Status (resistance unknown) were also included in some differential tests.

## RESULTS AND DISCUSSION

### Virulence frequencies

V4b and V6 were again detected in all isolates tested; V2, V8 and VTa2 were present in almost 100% of isolates. Although there has been significant selection for V2, V4b, V6 and V8 for several years (corresponding resistance present in 63%, 57%, 54%, 18% of winter wheat area in 2002, respectively), no known cultivars currently select for VTa2. These four most frequently detected virulence genes correspond to the resistance genes carried by the majority of the popular winter wheat cultivars: Claire (20% of winter wheat area in 2002), Consort (14%), Malacca (10%), Option (7%) and Tanker (9%). The frequency of V5, also high, has remained stable over the last few years, although there has been little or no selection during that period. The fluctuation in the frequency of VAx in recent years is probably partly

due to sampling bias. However, the addition of Xi19 to the HGCA Recommended List has resulted in an increase in the area of wheat grown which carries MlAx (6% in 2002)

**Table 1.** Differential cultivars used to determine virulence factors in isolates of wheat mildew, 2002.

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

Virulence for Soissons has continued to increase, although Soissons has retained its good level of resistance in the field. Reduction in the frequency of VSh is probably due to sampling bias: 7% of the isolates tested in 2002 were obtained from Shamrock, compared to 13% in 2001. The non-corresponding virulence frequency for VSh remained around 2%, demonstrating that this virulence is still rare on cultivars other than Shamrock. When Shamrock is no longer grown, it is likely that VSh will decline in the population unlike, for example, V5 and VTa2 which have remained at high frequencies in the absence of selection.

The frequencies of Vd, VTo, VBr, VSi2 and VSo have fluctuated over the last few years, mostly unrelated to changes in areas of the corresponding resistance factors. There is currently no selection for these virulences by winter wheat cultivars, with the exception of VTo, although this selection is restricted to 0.1% of the wheat grown (cultivar Spark). However, there is some selection for VBr by spring wheats, as Ashby (22.6% of spring wheat area in 2002) and Chablis (10.2%) both carry MlBr. The most popular spring cultivar Paragon (41% of spring wheat grown) carries no specific resistance to mildew. V3b and V17 remain present in the population, although the corresponding resistance genes have not been deployed in wheat cultivars grown in the UK.

**Table 2.** Frequency of wheat mildew virulence genes/factors, 1995-2002, and 2002 areas of winter cultivars with the corresponding resistance.

| | Frequency of virulence factors | | | | | | | | % area |
|---|---|---|---|---|---|---|---|---|---|
| **Virulence factor** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** | **2002#** |
| 2 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 99 | 63 |
| 3b | 4 | 3 | 4 | 1 | 2 | 1 | 4 | 6 | 0 |
| 4b | 88 | 93 | 98 | 100 | 99 | 99 | 100 | 100 | 57 |
| 5 | 92 | 93 | 95 | 88 | 91 | 88 | 90 | 89 | 0 |
| 6 | 89 | 96 | 99 | 100 | 100 | 99 | 100 | 100 | 54 |
| 8 | 95 | 96 | 98 | 97 | 99 | 97 | 98 | 98 | 18 |
| 17 | 10 | 15 | 16 | 8 | 22 | 2 | 9 | 13 | 0 |
| d | 19 | 33 | 26 | 18 | 6 | 12 | 25 | 24 | 0 |
| 2,Ta2 | 85 | 92 | 93 | 86 | 97 | 96 | 95 | 99 | 0 |
| To | 18 | 29 | 29 | 16 | 16 | 5 | 24 | 20 | <1 |
| Br | 21 | 32 | 30 | 16 | 15 | 8 | 24 | 27 | 0 |
| 5,Si2 | 22 | 32 | 21 | 17 | 20 | 8 | 8 | 15 | 0 |
| So | 10 | 15 | 15 | 10 | 6 | 4 | 6 | 11 | 0 |
| Ax | 11 | 24 | 20 | 7 | 1 | 1 | 10 | 8 | 7 |
| Ss | | | | 65 | 57 | 74 | 82 | 93 | 3 |
| Sh | | | | 3 | 0 | 4 | 16 | 8 | 1 |
| **Number of isolates tested** | **265** | **313** | **328** | **187** | **148** | **286** | **165** | **209** | |

# NIAB (2002)

## Frequency of pathotypes

Pathotype V2,4b,5,6,8,Ta2 continued to dominate the population, although levels have decreased in the last two years (Table 3). However, of the 49 pathotypes detected in 2002, 36 carried V2,4b,5,6,8,Ta2, combined with additional virulence factors. As these virulence genes/factors correspond to the resistance genes/factors of the most popular winter wheat cultivars, such pathotypes are potentially capable of infecting more than 80% of the winter wheat area grown.

## Complexity of isolates

The numbers of virulence genes/factors carried by isolates in 2002 were similar to 2001 (Table 4). The majority of the population carried six or more genes/factors, corresponding to the pathotypes containing V2,4b,5,6,8,Ta2. It is possible that the population has stabilised, with these six virulence genes/factors representing the bulk of the population, combined with a range of the remaining virulence genes/factors under test.

**Table 3.** Frequencies of the most commonly identified pathotypes, 1994-2002, as defined by the factors in Table 1, with the exception of MlSs (Soissons) and MlSh (Shamrock).

| | Frequency of pathotypes (%) | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Pathotype** | **1994** | **1995** | **1996** | **1997** | **1998** | **1999** | **2000** | **2001** | **2002** |
| 2,4b,5,6,8 | 8 | 8 | 4 | 3 | 9 | <1 | 2 | 1 | 0 |
| 2,4b,6,8,Ta2 | 2 | 3 | 1 | 2 | 6 | 5 | 8 | 5 | 2 |
| 2,4b,5,8,Ta2 | 4 | 2 | 1 | <1 | 0 | 0 | 1 | 0 | 0 |
| 2,4b,5,6,8,Ta2 | 26 | 38 | 35 | 42 | 38 | 57 | 61 | 41 | 36 |
| 2,4b,5,6,8,Ta2,To,Br | 5 | 6 | 4 | 7 | 5 | 9 | 1 | 10 | 8 |
| 2,4b,5,6,8,Ta2,Si2 | 2 | 4 | 6 | 4 | 5 | 11 | 2 | 1 | 1 |
| 2,4b,5,6,8,Ta2,Si2,So | 6 | 8 | 4 | 7 | 4 | 2 | 2 | 3 | 2 |
| 2,4b,5,6,8,d,Ta2 | 7 | 5 | 5 | 3 | 6 | 2 | 7 | 12 | 10 |
| 2,4b,5,6,8,d,Ta2,To,Br,Ax | 3 | 3 | 6 | 10 | 1 | <1 | 1 | 5 | 1 |
| **Number of pathotypes** | **71** | **57** | **59** | **44** | **35** | **22** | **37** | **44** | **49** |
| **Number of isolates tested** | **347** | **265** | **313** | **328** | **187** | **148** | **286** | **165** | **209** |

**Table 4.** Number of virulence factors in the wheat mildew population, 1997-2002.

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

* corresponding to the resistance genes/factors in Table 1, with the exception of Pm3b (Chul),
Pm17 (Amigo) and MlSs (Soissons).

## Infection of winter wheat cultivars

The majority of cultivars in current use are potentially at risk from well over 90% of the mildew population (Table 5). However, although carrying ineffective specific resistance, many of these cultivars have good non-specific resistance, *e.g.* Charger (no specific resistance, but resistance rating of 8). If Scorpion 25 and Xi19 increase in popularity, it is likely that the corresponding virulence (VAx) would increase.

**Table 5.** Proportion of mildew isolates able to infect winter wheat cultivars in HGCA Recommended List trials in 2002. (2003 Recommended List cultivars in **bold**; mildew resistance ratings in brackets.)

| Cultivar | Proportion (%) | Cultivar | Proportion (%) |
|---|---|---|---|
| Chardonnay (6) | 100 | **Wizard (8)** | 99 |
| **Charger (8)** | 100 | **Access (7)** | 98 |
| Chatsworth (5) | 100 | Brunel (7) | 98 |
| Goodwood (3) | 100 | **Buchan (7)** | 98 |
| **Hereward (5)** | 100 | Carlton (7) | 98 |
| **Solstice (5)** | 100 | **Equinox (5)** | 98 |
| Arran (6) | 99 | **Madrigal (7)** | 98 |
| **Biscay (6)** | 99 | **Napier (7)** | 98 |
| **Claire (4)** | 99 | **Savannah (8)** | 98 |
| **Consort (6)** | 99 | **Tanker (7)** | 98 |
| **Deben (6)** | 99 | **Einstein (7)** | 95 |
| Macro (6) | 99 | **Soissons (8)** | 93 |
| **Malacca (7)** | 99 | **Scorpion 25 (8)** | 8 |
| **Option (4)** | 99 | **Shamrock (2)** | 8 |
| Phlebas (7) | 99 | Warlock 24 (8) | 8 |
| **Riband (7)** | 99 | **Xi19 (8)** | 8 |
| **Richmond (6)** | 99 | **Robigus (9)** | 0 |
| Tellus (6) | 99 | | |

The resistance rating of Shamrock has now fallen to 2, making it the most susceptible wheat cultivar. Although the frequency of VSh is still relatively low, increasingly high disease levels have been observed on Shamrock in the last two years. This suggests that Shamrock has no effective field resistance upon which to rely once its specific resistance is overcome. Also, as virulence for Shamrock was low on non-corresponding cultivars, pathotypes containing VSh may compete less well in the mildew population.

Of the winter wheats, only Robigus carries resistance not yet overcome by the UK mildew population. This cultivar was resistant to all isolates tested and also to a selection of historic isolates carrying a range of virulence factors. Although many current cultivars carry good non-specific resistance to mildew and hence have resistance ratings of 7 or 8, Robigus is the first cultivar with a rating of 9 to be recommended since Stetson in 1983. The source of the resistance is unclear from its parentage. However, unlike Stetson, Robigus is very susceptible to yellow rust (rating 3).

## Resistance factors of new cultivars

The specific resistance genes/factors found to be carried by current winter and spring wheat cultivars in 2002 tests are shown in Table 6.

**Table 6.** Specific mildew resistance genes/factors in wheat cultivars (2003 Recommended List cultivars in **bold**).

| | | | |
|---|---|---|---|
| None | *Pm2,6* | *Pm6,Pm8* | *MlBr* |
| Chardonnay | Macro | **Madrigal** | Alder (S) |
| **Charger** | | **Tanker** | **Chablis (S)** |
| Chatsworth | *Pm2,4b,6* | | Shiraz (S) |
| Goodwood | Arran | *Pm2,Pm4b(pm6,Pm8?)* | |
| **Hereward** | **Biscay** | **Option** | *Pm2,MlBr* |
| **Imp (S)** | **Consort** | | **Ashby (S)** |
| **Paragon (S)** | **Deben** | *Pm4b,Pm6,Pm8 (Pm2?)* | **Belvoir (S)*** |
| **Solstice*** | **Malacca** | **Buchan** | |
| | **Riband** | **Equinox** | *MlSs* |
| *Pm2* | **Richmond*** | **Napier** | **Soissons** |
| **Ambient (S)** | **Wizard*** | **Savannah** | |
| Tellus | | | *MlSh* |
| **Wallace (S)** | *Pm8?* | *MlAx* | **Shamrock** |
| | Carlton | **Scorpion 25*** | |
| *Pm2+?* | | Warlock 24 | ? |
| **Einstein*** | *Pm4b,Pm8?* | **Xi19** | **Morph (S)** |
| | Brunel | | |
| *Pm2,Pm4b* | | *MlTo* | Rx ? |
| **Claire** | *Pm2,Pm4b,Pm8* | Spark | **Robigus*** |
| | **Access** | | Status (S) |
| *Pm6?* | | | **Tybalt (S)*** |
| Phlebas | (S) Spring wheat | *** New Recommendation** | |

Robigus (winter) and Status (spring) carry uncharacterised specific resistance factors, being resistant to all isolates with which they were tested. The origin of the resistance in Robigus is unknown; Status has Cadenza and Soissons in its parentage. Morph (spring) also carries unknown specific resistance; it was resistant to 93% of the 2002 isolates tested but was susceptible to pathotype V2,4b,5,6,8,Ta2,Ss in earlier resistance tests. The source of the resistance of Morph is unclear, as it is a derivative of Buster (winter) and Baldus (spring), both very susceptible cultivars. The new spring cultivar Tybalt also has a resistance rating of 9: although one parent is the susceptible Chablis, the resistance of the other parent is unknown. The remaining new cultivars tested carried resistance genes already detected in existing cultivars.

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# MILDEW OF BARLEY

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*Vra*, *Vg* and *Va12* were detected in all isolates tested in 2002. Virulence for *Ml(CP)*, *MlAb*, *MlLa* and *Mla7* was also present in over 90% of isolates tested. The increase in the frequency of *Va12* and *V(Ab)* over the last few years reflects the increase in popularity of cultivars carrying *Mla12* and *Ml(Ab)* e.g. Optic (*Mla12,Ml(Ab)*). *Vh* was less common in isolates derived from airborne spores and cultivars lacking *Mlh*. The frequency of *Vh* has increased over the last two years, following the increase in the area grown of cultivars carrying *Mlh* due to the popularity of winter cultivar Pearl. The most common pathotype, *Vh,Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1*, was more frequent in 2002, detected in 22% of isolates tested. The number of virulence factors carried by isolates in 2002 was similar to 2001. Few winter barley cultivars carry effective specific resistance, although some have good non-specific resistance. Only Vanessa, Leonie, Clara and Sequel carry effective specific resistance. Spring cultivars Kirsty and Novello appear to carry specific resistance not previously used in the UK, but nevertheless matched by low levels of virulence in the population. The majority of spring cultivars carry *mlo* resistance which remains effective in the field. Fewer isolates with partial virulence for *mlo* were detected, compared to the previous three years.

## INTRODUCTION

Infection was observed on winter barley soon after emergence in 2002 and developed considerably over the autumn and mild winter. By late winter, high mildew levels were present on susceptible cultivars, e.g. Regina, in eastern and western areas and lower leaf death was common. Less infection was found in other areas and on later sown crops. Frost and subsequent rain in March resulted in a decline in levels of disease. By GS31-32, infection was much less obvious as stems extended and lower leaves senesced, although Regina maintained higher levels of disease. Later, there was further disease development in most areas, particularly on Regina and Heligan.

In spring barley, mildew was present on the susceptible cultivar Optic in eastern areas during tillering. By GS31, infection could be found on all but the most resistant cultivars in most areas. Occasionally, very low levels of infection were found on *mlo* cultivars, particularly Riviera, in Cambridgeshire and Lincolnshire.

## METHODS

### Virulence survey

163 samples were received, mostly from East Anglia. 241 single colony isolates were tested, taken from leaf samples collected from the locations shown in Table 1. 38 samples failed to produce viable conidia.

**Table 1**. Locations from which samples were collected in 2002.

| Location | Number of isolates | Location | Number of isolates |
|---|---|---|---|
| NIAB, Cambridge | 145 | Cockle Park, Northumberland | 6 |
| Morley, Norfolk | 46 | Selby, Yorks. | 2 |
| Headley Hall, Yorks. | 22 | Shrewsbury, Salop | 2 |
| Spalding, Lincs. | 17 | Malton, Yorks. | 1 |
| Total number of isolates tested | | | 241 |

The 241 isolates tested were derived from 107 samples taken from the 20 spring and 29 winter cultivars shown in Table 2. An additional eight isolates were taken from breeding lines with unknown resistance.

**Table 2**. Cultivars from which leaf samples were collected in 2002.

Spring cultivars

| | isolates | | isolates | | isolates |
|---|---|---|---|---|---|
| Riviera | 14 | Kirsty | 4 | Colston | 2 |
| Optic | 8 | Novello | 4 | FDO 96-074 | 2 |
| Chalice | 6 | Prisma | 4 | Adonis | 2 |
| Spire | 6 | County | 4 | Global | 2 |
| Sebastian | 6 | Cocktail | 4 | Class* | 2 |
| Tavern | 6 | FDO 95-019 | 3 | Cellar | 1 |
| NSL 97-6016 | 5 | Apex | 2 | Breeding lines | 8 |

Winter cultivars

| | isolates | | isolates | | isolates |
|---|---|---|---|---|---|
| Regina | 12 | Haka | 6 | Diamond | 4 |
| Pearl | 11 | Heligan | 5 | Pedigree | 4 |
| Siberia | 8 | Swallow | 5 | Vertige | 4 |
| Kestrel | 8 | Sumo | 4 | Saigon | 3 |
| Antonia | 7 | Angela | 4 | Antelope | 2 |
| Leonie | 7 | Scylla | 4 | Gleam | 2 |
| Vanessa | 6 | Pastoral | 4 | Parasol | 2 |
| Jewel | 6 | Pict | 4 | Muscat | 2 |
| Opal | 6 | Fanfare | 4 | Clara | 2 |
| Carat | 6 | Sequel | 4 | | |

- Class previously called Topic

Plants of the susceptible spring cultivar Golden Promise were exposed to the local air spora on a roof in south east Cambridge in June and 98 single colony isolates taken from the resulting infection were tested.

Isolates were tested for virulence on detached leaves of the differential cultivars listed in Table 3.

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

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

The winter barley cultivars Vanessa, Leonie and Clara and the spring cultivars County, Tavern, Spire, Kirsty and Novello were also included in some tests.

### Virulence for *mlo* cultivars

A selection of isolates from 2002 which gave limited infection on the *mlo* differentials, Apex and Riviera, were tested on a range of cultivars thought to carry *mlo* resistance. Isolates deemed partially virulent to *mlo* from previous years (Slater & Clarkson, 2001) were included in the tests as controls.

## RESULTS AND DISCUSSION

### Virulence

Virulence frequencies calculated from the results of 2002 tests are shown in Table 4. *Vra*, *Vg* and *Va12* were detected in almost all isolates tested. There was considerable selection for these virulence factors, as almost half the barley grown in 2002 carried *Mlra*, while *Mlg* and *Mla12* were present in cultivars occupying 25% and 29% of the barley area respectively. Virulence for *Ml(CP)* and *Ml(Ab)* occurred in almost all the isolates, although *V(Ab)* was more common in isolates derived from the air spora. *VLa* and *Va7* were detected in over 90% of isolates tested; *VLa* was also more common in isolates from the air spora.

Virulence for *Mlh* and *Mla1* also occurred frequently (67% and 71% respectively). The frequency of *Vlh* was lower in the isolates derived from airborne spores and slightly lower on cultivars lacking *Mlh*, suggesting that this virulence is still responding to changes in selection pressure. The area of barley sown with cultivars carrying *Mlh* has increased since 1999, with Pearl (*Mlh,Mlra,Mlg,Ml(CP)*) currently the most popular winter barley cultivar. *Va1* remained frequent in the population despite selection by only 1% of the barley area, following the decline of cultivars such as Cooper (*MlLa, Mla1*) and Delibes (*Ml(Ab),Mla1*), popular in the mid 1990s.

**Table 4**. Virulence frequencies in single colony isolates of barley mildew from infected leaves (leaf sample) and from random samples of airborne spores, and the area of barley cultivars with the corresponding resistance factors in 2002.

| | % Frequency of virulence factors | | | % Area of corresponding |
|---|---|---|---|---|
| | Leaf sample | | Random samples of airborne spores | resistance # |
| Virulence gene | All leaf data | Non-corresponding virulence * | | |
| *Vh* | 89 | 85 | 67 | 30 |
| *Vra* | 100 | 100 | 100 | 48 |
| *Vg* | 98 | 98 | 100 | 25 |
| *V(CP)* | 97 | 96 | 98 | 25 |
| *Va6* | 20 | 17 | 19 | <1 |
| *VLa* | 91 | 91 | 96 | <1 |
| *Va12* | 99 | 99 | 100 | 29 |
| *Vk1* | 52 | 52 | 52 | 0 |
| *Va7* | 96 | 96 | 96 | 6 |
| *V(Ab)* | 94 | 93 | 99 | 20 |
| *Va1* | 74 | 73 | 71 | 1 |
| *Va9* | 15 | 15 | 14 | 0 |
| *vo* | 0 | 0 | 0 | 19 |
| *Va13* | 15 | 14 | 6 | 2 |
| *Va3* | 2 | 2 | 2 | 0 |
| No. of isols. | **241** | | **98** | |

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

\# NIAB (2002)

*Vk1* was detected in just over 50% of the isolates tested, although there has been no selection for this virulence for fifteen years. *Va6* and *Va9*, for which there is also no, or little, selection occurred in 19% and 14% of the population respectively. The occurrence of *Va13* was lower in the air spora than in isolates derived from infected leaves. Only 2% of commercial crops select for this virulence, although 5% of cultivars in spring barley Recommended List trials (the source of the majority of leaf samples) carry *Mla13*. The frequency of *Va3*, for which there has been no known selection in the UK over the years the survey has operated, was detected in 2% of the isolates tested.

Some isolates gave limited infection on Apex and Riviera in differential tests, but no true virulence for *mlo* was detected.

Virulence frequencies for 2002 are compared to those determined in previous years in Table 5. *Vh*, although decreasing in frequency from 1996 to 2000, has increased over the last two years, reflecting a rise in the area grown of cultivars carrying *Mlh* (9% in 1999, 33% in 2002).

**Table 5**. Virulence frequencies in barley mildew, 1993 to 2002.

| Virulence gene | Virulence frequency (%) * | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1993 | 1994 | 1995 | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 |
| *Vh* | 78 | 79 | 70 | 78 | 68 | 61 | 58 | 50 | 68 | 83 |
| *Vra* | 100 | 99 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| *Vg* | 96 | 95 | 95 | 96 | 95 | 97 | 97 | 97 | 99 | 99 |
| *V(CP)* | 92 | 88 | 90 | 90 | 93 | 94 | 95 | 96 | 98 | 97 |
| *Va6* | 35 | 31 | 34 | 30 | 25 | 31 | 26 | 23 | 19 | 20 |
| *VLa* | 22 | 25 | 31 | 56 | 58 | 72 | 89 | 88 | 95 | 92 |
| *Va12* | 72 | 67 | 71 | 70 | 73 | 76 | 87 | 88 | 99 | 99 |
| *Vk1* | 75 | 72 | 72 | 76 | 71 | 73 | 66 | 61 | 57 | 52 |
| *Va7* | 76 | 69 | 73 | 76 | 73 | 76 | 85 | 95 | 99 | 96 |
| *V(Ab)* | 76 | 74 | 67 | 62 | 52 | 53 | 71 | 79 | 95 | 95 |
| *Va1* | 18 | 23 | 27 | 38 | 36 | 45 | 64 | 65 | 67 | 73 |
| *Va9* | 29 | 34 | 33 | 37 | 33 | 32 | 25 | 29 | 28 | 15 |
| *Va13* | 38 | 43 | 37 | 41 | 39 | 25 | 19 | 11 | 17 | 13 |
| *Va3* | 1 | <1 | <1 | <1 | 1 | 1 | 1 | 5 | 1 | 2 |
| Number of isolates | 628 | 539 | 552 | 428 | 551 | 743 | 629 | 689 | 235 | 339 |

* Mean of leaf samples and random samples of airborne spores for each year. Data from Slater & Clarkson (2002).

*Vg*, *V(CP)* and *Va12* have become more frequent since 1994, now being detected in almost all the isolates tested. The area of barley cultivars carrying *Mlg,Ml(CP)* has fluctuated over the last ten years, and currently stands at its highest level since 1997. The increase in frequency of *Va12* reflects an increase in the area of cultivars carrying *Mla12*, particularly over the last five years. From 70% in 1996, when *Mla12* cultivars covered only 15% of the barley area, the frequency of *Va12* rose to 99% in 2002, following an increase in the popularity of *Mla12* cultivars, such as Optic (*Mla12,Ml(Ab)*). Recent years have also seen an increase in the frequency of *V(Ab)*, corresponding to an increase in the area of the corresponding resistance. Following a decline in the early 1990s, *Ml(Ab)*-carrying cultivars have occupied around 20% of the barley area since 1999, due also to the popularity of Optic.

There have also been increases in the frequency of virulence for *MlLa*, *Mla7* and *Mla1*, although there has been no corresponding increase in the areas of these resistances. *VLa* has increased steadily over the last ten years despite a low selective area, compared to the previous decade (26% in 1980, maximum 1% since 1998). *Va7* has also increased steadily. Although little selection in 2002, cultivars with *Mla7*, particularly Regina, occupied around 20% of the barley area from 1998 to 2000. The frequency of *Va1* has also increased, despite a reduction in the area of *Mla1* cultivars.

The declining area of cultivars carrying *Mla6*, *Mla9* and *Mla13* has resulted in a decrease in frequency of the corresponding virulence factors. *Vk1*, for which there has been no selection for several years, has also decreased in frequency.

Virulence for *Mlra* was maintained at 100%, while the frequency of *Va3* remained low.

## Complexity of isolates

The complexity of the barley mildew population is shown in Table 6. The number of virulence factors combined in isolates tested in 2002 was similar to 2001. 2% of the isolates tested carried 13 virulence factors, and were therefore capable of infecting all the major resistances in current cultivars, with the exception of *mlo*.

**Table 6**. Comparison of the complexity of isolates collected from 1993 to 2002.

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

* includes all virulences listed in Table 2

The number of pathotypes identified in 2002 is shown in Table 7. The commonest pathotype, *Vh,Vra,Vg,V(CP),VLa,Va12,Va7,V(Ab),Va1*, was represented by 22% of isolates tested, a two fold increase over the previous year. More pathotypes were detected than in 2001, but this probably reflects the increased number of isolates tested, as the ratio of number of pathotypes to number of isolates tested continued to fall. The trend towards the dominance of a few pathotypes observed since the mid 1990s continued.

**Table 7**. Number of pathotypes identified, 1995-2002.

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

## Infection of barley cultivars

The importance of non-specific resistance to confer effective resistance to mildew in the field is illustrated by the data in Table 8. Although any specific resistance carried by the majority of current winter cultivars is matched by a high proportion of the population, some of these cultivars carry good field resistance. Pearl (*Mlh,Mlra,Mlg,Ml(CP)*) and Angela (*Mlh,Mlra*) are both potentially at risk from over 80% of the population but have resistance ratings of 8. Some cultivars, e.g. Heligan and Pastoral, carry ineffective specific resistance matched by all the population, but have little additional non-specific resistance, as shown by their low ratings of 3. Such cultivars generally support moderate to high levels of disease in the field and require the application of fungicides to control mildew infection.

Sequel (*Mla6*), Vanessa, Leonie and Clara (resistance unknown) carry specific resistance currently matched by only a small proportion of the population. It is possible that frequencies of specific virulence for these cultivars would increase should they become widely grown; the levels of non-specific resistance and future performance would then become critical.

**Table 8**. Proportion of mildew isolates tested in 2002 able to infect barley cultivars in HGCA Recommended List trials (Rating for mildew in brackets)

| Winter cultivars | Proportion (%) | Winter cultivars | Proportion (%) |
|---|---|---|---|
| Heligan (3) | 100 | Angela (8) | 83 |
| Muscat (7) | 100 | Antonia (5) | 83 |
| Pastoral (3) | 100 | Haka (8) | 83 |
| Pict (6) | 100 | Kestrel (3) | 83 |
| Antelope (7) | 100 | Opal (7) | 83 |
| Cannock (3) | 100 | Parasol (7) | 83 |
| Carat (7) | 99 | Pearl (8) | 83 |
| Diamond (7) | 99 | Scylla (6) | 83 |
| Pedigree (6) | 99 | Siberia (6) | 83 |
| Fanfare (6) | 97 | Sequel (8) | 20 |
| Saigon (6) | 97 | Vanessa (8) | 20 |
| Swallow (7) | 97 | Leonie (8) | 19 |
| Regina (3) | 96 | Clara (7) | 13 |
| Vertige (6) | 96 | Sumo (7) | ? |

| Spring cultivars | Proportion (%) | Spring cultivars | Proportion (%) |
|---|---|---|---|
| Optic (7) | 95 | Cocktail (9) | 0 |
| Sebastian (6) | 95 | Colston (9) | 0 |
| County (8) | 73 | Chime (9) | 0 |
| Tavern (7) | 73 | Decanter (9) | 0 |
| Spire (8) | 13 | Global (9) | 0 |
| Kirsty (9) | 13 | Pewter (9) | 0 |
| Novello (9) | 1 | Prestige (9) | 0 |
| Adonis (9) | 0 | Riviera (9) | 0 |
| Cellar (9) | 0 | Static (9) | 0 |
| Chalice (9) | 0 | Thetford (9) | 0 |
| Class (9) | 0 | | |

Most of the spring barley cultivars in current use are at least moderately resistant in the field. Although the specific resistance of Optic and Sebastian has long been overcome, both cultivars display moderately good field resistance. Spire (*Mla13*), Kirsty and Novello (resistance unknown) are at risk by part of the population only (13%, 13%, 1% respectively). The degree of non-specific resistance carried by these cultivars will only become apparent if the levels of specific virulence rise as a result of increased selection. The remaining spring cultivars carry *mlo* resistance. This resistance was originally considered non-specific and durable. However, with the detection of partially virulent isolates (Schwarzbach, 1998), it now appears that *mlo* resistance may be of a more specific nature.

## Resistance factors in new cultivars

Spring cultivars Kirsty (newly recommended for 2003) and Novello appear to carry specific resistance not defined by the current differentials but nevertheless matched by low levels of virulence in the population. The remaining new cultivars in Recommended List trials in 2002 all probably carry *mlo* resistance, with the exception of Sebastian (*Mla12,Ml(Ab)*). Eight of the eleven spring cultivars on the HGCA Recommended List for 2003 carry *mlo*.

The new winter cultivars in trials in 2002 carried resistance already present in existing cultivars. Clara appears to carry unknown resistance, possibly similar to that carried by Vanessa and Leonie.

**Table 9.** Resistance genes of barley cultivars (2003 HGCA Recommended List cultivars in **bold**).

| None | *Mlra,Mla6* | *Mla13* |
|---|---|---|
| Antelope (W) | **Sequel** (W) | **Spire** (S) |
| **Cannock** (W) | | |
| | *Mla12* | *Mlo* |
| *Mlra* | **Jewel** (W) | Adonis (S) |
| **Heligan** (W) | | **Cellar** (S) |
| **Muscat** (W) | *Mlra,Mla12* | **Chalice** (S) |
| **Pict** (W) | **Carat** (W) | Class (S) |
| **Pastoral** (W) | **Diamond** (W) | **Cocktail** (S) |
| | Pedigree (W) | Colston (S) |
| *Mlh,Mlra* | | **Decanter** (S) |

| | | |
|---|---|---|
| **Angela** (W) | *Mlh,Mlg,Mla12* | Global (S) |
| **Haka** (W) | Parasol (W) | Pewter (S) |
| **Siberia** (W) | | **Prestige** (S) |
| | *Mla7 (Mlra?)* | **Riviera** (S) |
| *Mlh, Mlg* | **Regina** (W) | **Static** (S) |
| **Antonia** (W) | | **Thetford** (S) |
| Saigon (W) | *Mlh,Mlra,Mla7* | Vortex (S) |
| | **Vertige** (W) | |
| *Mlra,Mlg,Ml(CP)* | | Unknown |
| **Fanfare** (W) | *Mla12,Ml(Ab)* | Clara (W) |
| Swallow (W) | **Optic** (S) | **Kirsty** (S) |
| | Sebastian (S) | **Leonie** (W) |
| *Mlh,Mlra,Mlg,Ml(CP)* | | Novello (S) |
| **Kestrel** (W) | *Mla1(Ml(Ab),MlLa?),* | **Sumo** (W) |
| **Opal** (W) | County (S) | **Vanessa** (W) |
| **Pearl** (W) | Tavern (S) | |
| **Scylla** (W) | | |

(W) winter cultivar (S) spring cultivar

## Virulence for *mlo* cultivars

Further tests were carried out with 2001 isolates suspected of carrying partial virulence for *mlo*. Although a small number of isolates consistently gave low levels of infection on a range of *mlo* cultivars in tests, none matched the levels of virulence detected in 1998 and 1999.

Following a general rise in the last four years, fewer isolates gave low levels of infection on Apex and Riviera, the *mlo* differentials, in tests in 2002 (Table 10). A selection of these isolates was further tested on a range of *mlo* carrying cultivars, together with isolates from 2002 which gave no infection on Apex and Riviera in differential tests and control isolates from previous years' tests. The 2002 isolates which gave infection on Apex and Riviera repeatedly showed partial virulence for mlo cultivars Apex, Riviera, Chalice, Static and Decanter. In one test, the levels of partial virulence of the 2002 isolates were similar to the partially virulent control isolates, but levels in a further test were higher. In both tests, Apex, Riviera and Chalice carried the highest levels of infection, while fewer colonies developed on Static and Decanter.

**Table 10**. Proportion of isolates infecting Apex and Riviera in differential tests, 1996-2002 (as percentage of isolates tested)

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

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## MILDEW OF OATS

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## INTRODUCTION

Mildew was at higher levels in the winter and spring crops in 2002 than in the previous two seasons when it was late developing. This was reflected in a higher number of samples being received. Twenty-five samples came from winter crops and nine from spring oat cvs (Table 1).

**Table 1** Source cultivars of 2002 oat mildew samples

| Cv. | No. of samples | Cv. | No. of samples | Cv. | No. of samples |
|---|---|---|---|---|---|
| Winter oat | | | | Spring oat | |
| Jalna | 4 | Lexicon | 2 | Firth | 2 |
| Millennium | 3 | Buffalo | 2 | Winston | 2 |
| Kingfisher | 2 | 93AW2/5/6/3 | 2 | Emotion | 1 |
| Hendon | 2 | Gerald | 2 | Drummer | 1 |
| Icon | 2 | Ayr | 1 | SW Argyle | 1 |
| Grafton | 2 | CPBT W01 | 1 | Markant | 1 |
| | | | | Banquo | 1 |

The samples came from 4 locations, the majority being from two trial sites, Cockle Park and NIAB headquarters.

**Table 2** Geographic locations of oat mildew samples received in 2002

| Location | No. of samples |
|---|---|
| NIAB, Cambridge | 11 |
| Cockle Park, Northumberland | 18 |
| Mid Glamorgan | 4 |
| Shropshire | 1 |

## METHODS

Isolates of *Blumeria graminis* DC Speer f.sp. *avenae* were cultured from 18 samples and inoculated onto seedlings of the differential cvs (Table 3) grown in a spore-proofed glasshouse. 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 3** 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, 2 virulence combinations were identified in the 2002 isolates. OMV-1,2,3 (race 5) has been at a high frequency for several years and it was found in 15 isolates from 2002. The other virulence combination OMV-1,2,3,4 (race 7) was found in 3 isolates cultured from samples of cv. Jalna from Cockle Park, and cvs Millennium and Winston from Mid Glamorgan. Race 7 has remained at a low frequency since it was first identified in 1980. It differs from race 5 in carrying virulence to cv. Cc6490 (OMV-4), a translocation line carrying a chromosomal fragment from *Avena barbata*. Resistance conferred by this gene is not known to be deployed in any commercial cvs but it may be carried in some breeding lines.

# YELLOW RUST OF WHEAT

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## SUMMARY

Isolates carrying the virulence combination WYV9,17,CV, which are virulent on the cultivars Oxbow, Robigus and Wizard, comprised about 50% of the isolates tested in 2002. A significant number of established and new cultivars maintained their resistance when challenged with the most recent yellow rust pathotypes. There were indications of the possible emergence in 2002 of isolates combining WYV9,17,CV with WYV6. If confirmed, this new pathotype may prove to have implications for certain cultivars that are currently resistant.

## INTRODUCTION

Yellow rust was more widespread in 2002 than the preceding year, when incidence of the disease was very low. Following mild conditions in the late autumn and early winter, yellow rust infection was apparent by late winter. The wet spring slowed spread of the disease temporarily, but infection then built up in many trials, becoming severe on susceptible cultivars. Although yellow rust was reported in commercial crops, outbreaks were relatively restricted. This was due at least in part to the small area (about 6%) of highly susceptible varieties, with ratings of 3 or below (Table 1). Over half of the wheat area grown was of varieties with good resistance (ratings 6 and above).

## SEEDLING VIRULENCE TESTS OF ISOLATES COLLECTED IN 2002

### Methods

112 samples were received between March and July 2002 (Table 1). Although the majority of these came from East Anglia, a number were received from other regions, including Scotland (Table 2). The majority of the samples were collected from trial plots, with relatively few coming from commercial crops.

Due to technical problems, only 36 isolates were tested for virulence. However, these were carefully selected to represent a range of source cultivars and locations, with emphasis on those most likely to represent new or recent pathotypes. Virulence tests were carried out on seedlings of the differential cultivars shown in Table 3, using the methods described by Priestley, Bayles and Thomas, 1984. A number of additional cultivars, of particular relevance to UK breeding, were included in the tests. Some of these possess resistance that continues to be effective against all known UK pathotypes.

**Table 1**. UK winter wheat cultivars for 2002, yellow rust resistance ratings (1-9), area grown, number of samples received and number of isolates tested.

| Cultivar | WYR factors | 1-9 resistance rating * | % Area grown# | No. of samples received | No. of isolates tested |
|---|---|---|---|---|---|
| **Claire** | Rx+APR | 9 | 20.2 | 0 | 0 |
| **Consort** | CV+? | 5 | 14.0 | 7 | 4 |
| **Malacca** | Rx+APR | 9 | 10.4 | 1 | 1 |
| **Tanker** | 9 | 5 | 8.6 | 4 | 1 |
| **Option** | R | 9 | 6.9 | 0 | 0 |
| **Xi 19** | R | 9 | 6.4 | 0 | 0 |
| **Deben** | Rx | 9 | 4.0 | 0 | 0 |
| **Access** | 6,9,17 | 3 | 3.2 | 6 | 2 |
| **Hereward** | CV | 5 | 3.1 | 0 | 0 |
| **Soissons** | 3 | 7 | 3.1 | 0 | 0 |
| **Napier** | 6,9,17 | 3 | 2.5 | 2 | 0 |
| **Savannah** | 9,17 | 5 | 2.5 | 11 | 1 |
| **Solstice** | R | 9 | 2.0 | 0 | 0 |
| **Charger** | 6+APR | 8 | 1.3 | 0 | 0 |
| **Equinox** | 6,17 | 4 | 0.9 | 1 | 0 |
| **Riband** | 13 | 6 | 0.8 | 4 | 1 |
| **Shamrock** | CV+? | 8 | 0.5 | 0 | 0 |
| Goodwood | ? | 7 | 0.4 | 2 | 2 |
| **Robigus** | (9,17,CV)? | 3 | 0.2 | 10 | 6 |
| **Biscay** | 9,17 | 4 | 0.1 | 5 | 1 |
| **Madrigal** | 6,9,17 | 3 | 0.1 | 5 | 3 |
| **Wizard** | (9,17,CV)? | 4 | 0.1 | 3 | 1 |
| Brigadier | 9,17 | 1 | <0.1 | 1 | 1 |
| Brunel | (9,17,CV)? | 5 | <0.1 | 4 | 1 |
| **Buchan** | 9,17 | 3 | <0.1 | 11 | 7 |
| Carlton | 17? | 6 | <0.1 | 1 | 1 |
| **Imp** (spring) | R | 9 | <0.1 | 1 | 1 |
| Other cvs | ? | - | - | 33 | 2 |
| **TOTAL** | | | | **112** | **36** |

* Rating shown is that for 2003, or most recent where cultivar no longer recommended. Cultivars recommended for 2003 in **bold.**

\# NIAB (2002)

**Table 2**. Locations from which isolates were collected in 2002.

| Region | County | No. samples received | No. isolates tested |
|---|---|---|---|
| South East | Essex | 1 | 1 |
| | Hertfordshire | 1 | 1 |
| East Anglia | Cambridgeshire | 49 | 21 |
| | Norfolk | 38 | 9 |
| | Suffolk | 1 | 0 |
| East Midlands | Lincolnshire | 5 | 1 |
| | Leicestershire | 4 | 0 |
| West Midlands | Warwickshire | 1 | 0 |
| Yorkshire/Humberside | Yorkshire | 4 | 1 |
| North East | Northumberland | 5 | 1 |
| Scotland | Scotland | 3 | 1 |
| **TOTAL** | | **112** | **36** |

**Table 3**. Differential cultivars used in seedling virulence tests in 2002.

| Differential cultivar | WYR factor | Gene designation |
|---|---|---|
| Core set | | |
| Chinese 166 | WYR 1 | *Yr1* |
| Kalyansona | WYR 2 | *Yr2* |
| Vilmorin 23 | WYR 3 | *Yr3* + |
| Nord Desprez | WYR 3 | *Yr3* + |
| Hybrid 46 | WYR 4 | *Yr4* |
| Heines Peko | WYR 2,6 | *Yr2,Yr6* |
| Heines Kolben | WYR 2,6 | *Yr2,Yr6* |
| Lee | WYR 7 | *Yr7* |
| Reichersberg 42 | WYR7 | *Yr7*+ |
| Compair | WYR 8 | *Yr8* |
| Kavkaz x 4 Federation | WYR 9 | *Yr9* |
| Clement | WYR 9 | *Yr9* |
| Moro | WYR10 | *Yr10* |
| Yr15/6*AvS | WYR15 | *Yr15* |
| VPM 1 | WYR17 | *Yr17* |
| Rendezvous | WYR17 | *Yr17* |
| Carstens V | WYR CV | *Yr 32** |
| Avocet 'R' | WYR A | *YrA* |
| Suwon 92 x Omar | WYR So | *Yr Suwon 92/Omar* |
| Strubes Dickkopf | WYR Sd | *Yr Strubes Dickkopf* |
| Spaldings Prolific | WYR Sp | *Yr Spaldings Prolific* |
| Additional cvs | | |
| Beaver | WYR 6,9 | *Yr6,Yr9* |
| Hereward | CV + | |
| Oxbow | | CV+?9 |
| Consort CV +?9 | | |
| Vivant | CV + | |
| Flame | CV + | |
| Buster | R | |
| Cadenza | R | |
| Option | R | |
| Solstice | R | |
| Xi 19 | R | |

* McIntosh, pers. com.

## Results

The results of the 2002 virulence tests, together with data from 1988-2001 (Bayles *et al.* 2002), are shown in Table 4. Virulence frequencies should be interpreted with caution, due to the non-random nature of the sampling and selection of isolates for testing, and the relatively small numbers of isolates tested in some years.

As in previous years, the virulences WYV1, WYV2 and WYV3 were detected in almost all isolates (97%), as was WYVA. Other virulences found at high frequencies included WYV4, WYV9, WYV17, WYVCV, WYVSo and WYVSd, identified in between 63% and 88% of isolates. Of these, only WYVCV appears to have changed in frequency over the past 5 years. This virulence has increased steadily since isolates possessing the combination WYV9,17,CV were first detected on the previously resistant cultivar Oxbow in 2000.

**Table 4**. Frequency of virulence factors from 1988 to 2002.

| **Virulence for** | **88** | **89** | **90** | **91** | **92** | **93** | **94** | **95** | **96** | **97** | **98** | **99** | **00** | **01** | **02** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| WYR 1 | 68 | 62 | 85 | 91 | 88 | 89 | 65 | 90 | 97 | 100 | 99 | 99 | 100 | 100 | 97 |
| WYR 2 | 100 | 100 | 100 | 100 | 100 | 98 | 100 | 99 | 97 | 100 | 99 | 99 | 100 | 100 | 97 |
| WYR 3 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 97 |
| WYR 4 | 78 | 97 | 91 | 86 | 86 | 89 | 86 | 67 | 59 | 47 | 79 | 87 | 90 | 74 | 63 |
| WYR 6 | 72 | 57 | 69 | 64 | 88 | 68 | 41 | 35 | 16 | 1 | 7 | 21 | 32 | 39 | 31 |
| WYR 7 | 6 | 2 | 9 | 19 | 7 | 8 | 4 | 0 | 3 | 7 | 4 | 10 | 4 | 0 | 3 |
| WYR 8 | | | | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| WYR 9 | 66 | 99 | 94 | 88 | 76 | 84 | 94 | 95 | 97 | 99 | 99 | 99 | 92 | 90 | 88 |
| WYR 17 | | | | | | | | 57 | 84 | 99 | 99 | 100 | 96 | 77 | 88 |
| WYR CV | | | | | | | 75 | 55 | 9 | 13 | 1 | 4 | 16 | 42 | 73 |
| WYR A | | | | | | | | | | | 84 | 91 | 88 | 90 | 97 |
| WYR So | | | | | | | | | | | 78 | 91 | 90 | 77 | 67 |
| WYR Sd | | | | | | | | | | | 100 | 98 | 100 | 84 | 81 |
| WYR Sp | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 |
| Additional cvs | | | | | | | | | | | | | | | |
| Hereward | CV + | | | | 36 | 47 | 35 | 10 | 6 | 10 | * | * | * | * | 44 |
| Oxbow | CV +9? | | | | | | | | | | | | 16 | 32 | 50 |
| Consort | CV +9? | | | | | | | | | | | | | 36 | 33 |
| Vivant | CV + | | | | | | | | | | | | | | 25 |
| Flame | CV + | | | | | | | | | | | | | | 3 |
| Parade* | R | | | | | 3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Cadenza | R | | | | | | | | | | | | | 0 | 0 |
| Option | R | | | | | | | | | | | | | | 0 |
| Solstice | R | | | | | | | | | | | | | | 6 |
| Xi19 | R | | | | | | | | | | | | | | 0 |
| No. of isolates | 71 | 156 | 67 | 42 | 77 | 63 | 49 | 83 | 32 | 138 | 94 | 97 | 50 | 31 | 36 |

* or Buster (believed to carry same resistance)

The frequency of WYV6, which has fluctuated widely over the past 15 years in line with the area of varieties carrying the corresponding resistance, remained at around 30% for the third year running.

WYV7 remained at a very low level and was confirmed in only a single isolate. Once again, no virulence was detected for WYR8 or for WYRSp.

Virulence for the cultivars Oxbow, Hereward, Consort and Vivant ranged from 25% to 50%. Isolates virulent on these cultivars all possessed WYVCV, confirming that the cultivars carry the Carstens V resistance in common. However, isolates virulent on one cultivar were not invariably virulent on the others, indicating that they possess different additional resistance factors. Two isolates, provisionally identified as carrying the new virulence combination WYV6,9,17,CV, were virulent on the previously resistant cultivar Solstice. These isolates are being re-examined. No virulence was detected for Option, Buster or Xi19.

Table 5 compares the frequencies of pathotypes detected in 2000, 2001 and 2002. The most common pathotype was again WYV1,2,3,4,9,17,CV. The majority of isolates tested (67%) carried 6 or more virulence factors, although some simple pathotypes were detected e.g. WYV3, WYV1,2,3. Five isolates appeared to possess the previously undetected virulence combination WYV6,9,17,CV, although this has yet to be confirmed.

**Table 5**. Pathotype frequencies (%) for 2000 - 2002

| Pathotype* | 2000 | 2001 | 2002 |
|---|---|---|---|
| 1,2,3,4,9,17,CV | 16 | 32 | 31 |
| 1,2,3,9,17,CV | | 6 | 11 |
| 1,2,3,4,6,9,17 | 24 | 29 | 6 |
| 1,2,3,6,9,17 | 4 | 6 | 6 |
| 1,2,3,9,17 | 4 | 3 | 6 |
| 1,2,3,6,9,17,CV | | | 6 |
| 1,2,3,4,6,9,17,CV | | | 6 |
| 3 | | | 3 |
| 1,2,3 | | 3 | 3 |
| 1,2,CV | | | 3 |
| 1,2,3,4 | | 3 | 3 |
| 1,2,3,4,17 | | | 3 |
| 1,2,3,4,6,7,9,17 | | | 3 |

* Includes virulence for the first 18 differentials listed in Table 3 only, as being of most relevance to the UK.

## ADULT PLANT TESTS

### Methods

Details of isolates selected for adult plant tests in 2002 are shown in Table 6. Adult plant tests were grown in field isolation nurseries. Seedling tests of the same isolates and cultivars were carried out under standard controlled environment conditions.

**Table 6.** Isolates used in adult plant tests in 2002

| Isolate number | Location | Cultivar | Virulence |
|---|---|---|---|
| **2001 isolates** | | | |
| **01/7** | Cambs | Tanker | 1,2,3,4,9 |
| **01/12** | Cambs | Consort | 1,2,3,4,9,17,CV |
| **01/28** | Yorks | Access | 1,2,3,4,6,9,17 |
| **01/31** | Cambs | Consort | 1,2,3,4,9,17,CV |
| **01/36** | Lincs | Apollo | 1,2,3,4,9,17,CV |
| **01/45** | Lincs | Phlebas | 1,2,3,4,6,9,17 |
| **01/47** | Lincs | Oxbow | 1,2,3,4,9,17,CV |
| **Control isolates** | | | |
| **87/13** | Lincs | Slejpner | 1,2,3,9 |
| **95/88** | Cambs | Encore | 1,2,3,4,6,9 |
| **98/108** | Lincs | Shamrock | 2,3,4,6,CV,He |

## Results

Adult plant test results are shown in Table7. Seedling test data were used to clarify the specific resistance factors (WYR) listed in the table and to confirm the specific virulence of the isolates.

In many of the nurseries high levels of yellow rust developed on cultivars known to be resistant to the inoculating isolate e.g. the WYR17 and WYRCV groups of cultivars inoculated with isolates such as 87/13, 01/7 and 95/88, which lack the corresponding virulences WYV17 and WYVCV. Analysis of rust samples taken from nurseries early in the season indicated that this was due to natural infection before inoculation.

The resistance of fifteen cultivars at the top of the table remained effective against the most recent yellow rust pathotypes. Levels of infection on the remaining 25 susceptible cultivars were in line with their HGCA disease resistance ratings, which reflect their differing levels of partial resistance once specific resistance has been matched by the pathogen.

Of the five cultivars added to the HGCA Recommended List for 2003, two (Scorpion 25 and Richmond) were resistant to all isolates. Robigus (rating = 3) and Wizard (rating = 4) are susceptible to isolates that are virulent on Oxbow (WYV9,17,CV). Both cultivars are likely to be at particular risk in those areas of the UK most prone to yellow rust epidemics. Einstein has an intermediate level of partial resistance and appears unlikely to pose a major problem for yellow rust control.

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

| **Isolate source cv** | | | **87/13** Slejpner | **01/7** Tanker | **95/88** Encore | **01/45** Phlebas | **01/28** Access | **01/36** Apollo | **01/12** Consort | **01/31** Consort | **01/47** Oxbow | **98/108** Shamrock |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **seedling virulence** | | | 1,2,3,9 | 1,2,3,4,9 | 1,2,3,4,6, 9 | 1,2,3,4,6, 9,17 | 1,2,3,4,6, 9,17 | 1,2,3,4,9, 17,CV | 1,2,3,4,9, 17,CV | 1,2,3,4,9, 17,CV | 1,2,3,4,9, 17,CV | 2,3,4,6, CV,He |
| **Cultivar** | **WYR** | **Resist -ance (1-9)** | | | | | | | | | | |
| Option | R | 9 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 0 |
| Solstice | R | 9 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 2 |
| Richmond | R | 8 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 |
| Tellus | R | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Macro | R | 8 | 0 | 1 | 1 | 1 | 2 | 0 | 0 | 0 | 0 | 0 |
| Cadenza | R | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Warlock 24 | R | 9 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Scopion 25 | R | 9 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Xi19 | R | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 |
| Arran | R | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Chatsworth | R | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 |
| Claire | Rx + APR | 9 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Deben | Rx + APR | 9 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| Malacca | Rx + APR | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Apostle | 2,6 + APR | 9 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Brigadier | 9,17 | 1 | 42 | 44 | 34 | 29 | 28 | 29 | 46 | 36 | 37 | 40 |
| Buchan | 9,17 | 3 | 17 | 16 | 27 | 21 | 21 | 11 | 15 | 15 | 19 | 19 |
| Savannah | 9,17 | 5 | 17 | 16 | 14 | 16 | 12 | 13 | 15 | 11 | 15 | 16 |
| Carlton | 17? | 6 | 12 | 9 | 15 | 15 | 10 | 5 | 6 | 6 | 7 | 14 |
| Access | 6,9,17 | 3 | 17 | 13 | 12 | 18 | 14 | 14 | 10 | 3 | 12 | 24 |
| Madrigal | 6,9,17 | 3 | 13 | 19 | 14 | 20 | 15 | 12 | 12 | 11 | 13 | 35 |
| Napier | 6,9,17 | 3 | 16 | 14 | 7 | 18 | 15 | 13 | 15 | 7 | 10 | 26 |
| Phlebas | 6,9,17 | 7 | 5 | 6 | 7 | 12 | 8 | 0 | 2 | 2 | 3 | 10 |
| Carstens V | CV | * | 6 | 13 | 6 | 10 | 12 | 7 | 7 | 8 | 6 | 11 |
| Consort | CV+? | 5 | 9 | 6 | 7 | 20 | 4 | 15 | 5 | 9 | 8 | 3 |
| Hereward | CV+? | 5 | 11 | 6 | 7 | 4 | 4 | 9 | 6 | 9 | 15 | 13 |
| Shamrock | CV+? | 8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 |
| Goodwood | 6,CV? | 7 | 3 | 0 | 5 | 6 | 2 | 0 | 0 | 0 | 0 | 12 |
| Brunel | 9?,CV | 5 | 10 | 9 | 11 | 7 | 7 | 11 | 7 | 9 | 10 | 4 |
| Oxbow | 9?,CV | 2 | 20 | 16 | 27 | 17 | 12 | 23 | 15 | 20 | 23 | 12 |
| Robigus | 9?,CV | 3 | 23 | 13 | 22 | 15 | 9 | 28 | 15 | 20 | 25 | 12 |
| Wizard | 9?,CV | 4 | 18 | 13 | 14 | 14 | 7 | 16 | 11 | 13 | 18 | 7 |
| Chardonnay | 6? | 5 | 9 | 8 | 5 | 14 | 15 | 6 | 5 | 1 | 3 | 10 |
| Charger | ?+APR | 8 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 6 |
| Einstein | 6? | 6 | 1 | 9 | 3 | 2 | 7 | 0 | 3 | 2 | 0 | 11 |
| Hornet | 6,9 | 2 | 23 | 18 | 29 | 19 | 21 | 14 | 18 | 15 | 12 | 29 |
| Slejpner | 9 | 2 | 39 | 34 | 37 | 38 | 36 | 36 | 40 | 35 | 33 | 39 |
| Tanker | 9 | 5 | 11 | 11 | 12 | 12 | 9 | 5 | 10 | 8 | 7 | 7 |
| Riband | 13 | 7 | 7 | 8 | 11 | 9 | 13 | 7 | 4 | 12 | 4 | 8 |
| Hobbit | 14 | 2 | 22 | 15 | 30 | 18 | 19 | 14 | 11 | 19 | 25 | 29 |

## CONCLUSIONS

Virulence for Oxbow, first detected in 2000, was identified in about 50% of the isolates tested in 2002. These isolates all carried the virulence combination WYV9,17,CV. This virulence combination is now clearly common in the UK yellow rust population and could potentially cause serious problems if cultivars with the 'Oxbow resistance' become widely grown. Since two such cultivars were added to the HGCA Recommended List for 2003, vigilance will be required during the next few seasons.

There were indications of the possible emergence of a further new virulence combination in 2002. If confirmed, the combination of WYV9,17,CV with WYV6 is likely to have implications for several currently resistant cultivars.

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# YELLOW RUST OF BARLEY

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## SUMMARY

Yellow rust of barley was more widespread in 2002 than at any time since the 1980s. The recent popularity of highly susceptible winter barley cultivars has contributed to this increase. Pathogen isolates tested in 2002 varied in virulence for the traditional differential cultivars and for a set of UK cultivars. UK winter barley cultivars differ widely in partial resistance. Some may carry unidentified specific resistance.

## INTRODUCTION

Reports of yellow rust on barley were more frequent in 2002 than for many years, resulting in a greatly increased number of samples. Susceptible cultivars (resistance ratings of 5 or below) were grown on nearly 40% of the winter barley and spring barley areas.

## METHODS

53 samples of barley yellow rust were received in 2002. Isolates were successfully cultured from 35 samples, but due to technical problems only eight isolates were tested. The source of isolates is shown in Table 1.

**Table 1**. Cultivars from which samples of barley yellow rust were collected in 2002.

| Source cultivar | Resistance rating (1-9)* | area **(% of appropriate crop) | Number of samples received | Number of isolates tested |
|---|---|---|---|---|
| Regina (w) | 2 | 10.0 | 9 | 0 |
| Siberia (w) | 4 | 6.9 | 4 | 1 |
| Riviera (s) | 6 | 6.6 | 2 | 0 |
| Vanessa (w) | 3 | 1.3 | 2 | 1 |
| Antonia (w) | 6 | 3.7 | 1 | 1 |
| Global (s) | 8 | <0.1 | 1 | 1 |
| Kirsty (s) | 5 | 0.1 | 1 | 1 |
| Milena (w) | - | 0 | 1 | 1 |
| Novello (s) | 6 | 0 | 1 | 1 |
| Spire (s) | 5 | 4.9 | 1 | 1 |
| Other winter cultivars and breeding lines | | | 17 | |
| Other spring cultivars and breeding lines | | | 13 | |
| **TOTAL** | | | **53** | **8** |

(w) : winter cultivar (s) : spring cultivar
* Source: HGCA Recommended Lists for 2003
** Source: NIAB seed production statistics

The greatest number of samples originated from Northumberland and Cambridgeshire (Table 2).

**Table 2.** Locations from which samples of yellow rust were collected in 2002.

| Region | County | No. samples received | No. isolates tested |
|---|---|---|---|
| SE | Essex | 1 | 1 |
| SW | Gloucestershire | 1 | 0 |
| EA | Cambridgeshire | 14 | 3 |
| | Norfolk | 1 | 0 |
| | Suffolk | 2 | 0 |
| EM | Derbyshire | 1 | 0 |
| | Lincolnshire | 1 | 0 |
| YH | Humberside | 1 | 0 |
| | Yorkshire | 1 | 0 |
| NE | Cleveland | 1 | 0 |
| | Co. Durham | 3 | 0 |
| | Northumberland | 26 | 4 |
| | **TOTAL** | **53** | **8** |

The standard differential cultivars and additional cultivars used in seedling virulence tests are listed in Table 3. Additional cultivars were chosen on the basis of earlier indications that they may carry unidentified resistances effective against some isolates but not others.

**Table 3**. Differential cultivars used to test isolates of barley yellow rust in 2002.

| Cultivar | BYR factor | Type * | Year virulence first detected |
|---|---|---|---|
| Astrix | 1 | O | ) 1960 |
| Atem | 1 | O | ) |
| Bigo | 2 | O | ) |
| Varunda | 2 | O | ) 1972 – 75 |
| Mazurka | 2 | S | ) |
| Triumph | 3 | ?S | 1983 |
| Additional cultivars | | | |
| Jackpot | Rx ? | | |
| Gleam | Rx ? | | |
| Pearl | Rx ? | | |
| Fanfare | Rx ? | | |
| Manitou | Rx ? | | |
| Leonie | Rx ? | | |
| Derkado | Rx ? | | |
| Optic | Rx ? | | |

* O = overall , resistance effective at all growth stages
S = seedling, resistance ineffective at adult growth stages

Seedling tests were also carried out on 34 winter barley cultivars in HGCA Recommended List trials, using four contrasting isolates from previous years' surveys.

## RESULTS

Virulence frequencies for the years 1984 – 2002 are shown in Table 4 (no samples were received in '96, '97 or '98). These frequencies should be viewed with caution due to the low incidence of the disease and small number of samples. All isolates tested in 2002 possessed BYV1, with half also possessing BYV3. There was no evidence of BYV2.

Isolates also varied in virulence for the eight 'additional' cultivars (Table 5). Although nothing is known about the genetic basis of their resistance, these cultivars may help to discriminate meaningfully between UK isolates in future tests.

**Table 4**. Percentage frequency of barley yellow rust virulence factors for 1984 – 2002.

| | ’84 | ’87 | ’89 | ’90 | ’91 | ’92 | ’93 | ’94 | ’95 | ’99 | ’00 | ’01 | ’02 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| BYV1 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 86 | 100 | 100 |
| BYV2 | 100 | 100 | 100 | 0 | 100 | 100 | 100 | 100 | 100 | 100 | 71 | 0 | 0 |
| BYV3 | 86 | 22 | 75 | 0 | 0 | 0 | 0 | 100 | 0 | 100 | 71 | 0 | 50 |
| No. of isolates | 7 | 9 | 4 | 1 | 1 | 2 | 1 | 1 | 3 | 1 | 7 | 3 | 8 |

**Table 5**. Relative frequency of virulence for additional cultivars, 2002.

| Cultivar | Relative number of virulent isolates (%) |
|---|---|
| Leonie | 100 |
| Jackpot | 88 |
| Pearl | 50 |
| Manitou | 50 |
| Gleam | 38 |
| Fanfare | 38 |
| Optic | 13 |
| Derkado | 0 |

Table 6 shows the results of seedling tests of winter barley cultivars in Recommended List trials. The four isolates used to test the cultivars differed from one another when judged by the reactions of the standard differential cultivars. However, their apparent virulence factors were inconsistent with original test results.

Twenty one of the thirty four winter barley cultivars tested were susceptible, at the seedling stage, to all four isolates. However, their published resistance ratings, reflecting the resistance of adult plants in field tests, range from 2 (highly susceptible) to 9 (resistant). This indicates that the cultivars differ widely in partial resistance. A further 12 cultivars were seedling susceptible to certain isolates but not to others, indicating that they may possess specific resistances in addition to variable levels of partial resistance.

A single cultivar, Parasol, was resistant to all isolates and currently has a resistance rating of 9. Cultivars such as Parasol, and the spring barley Derkado, require close monitoring for any sign of adaptation in the pathogen.

**Table 6**. Seedling tests of winter barley cultivars (reaction types classified as resistant (R) = average infection type 0-2 or susceptible (S) = average infection type >2)

| Isolate code | | 83/39 | 84/2 | 94/4 | 01/2 |
|---|---|---|---|---|---|
| BYV original | | 1,2,3 | 1,2 | 1,2,3 | 1 |
| *BYV apparent** | | *0* | *3* | *1,(2),3* | *1,2,3* |
| Cultivar | Resistance rating (1-9)** | | | | |
| Pedigree | 9 | S | S | S | S |
| Haka | 8 | S | S | S | S |
| Clara | 8 | S | S | S | S |
| Fanfare | 7 | S | S | S | S |
| Angela | 6 | S | S | S | S |
| Antonia | 6 | S | S | S | S |
| Opal | 6 | S | S | S | S |
| Pict | 6 | S | S | S | S |
| Jackpot | 6 | S | S | S | S |
| Pearl | 6 | S | S | S | S |
| Vertige | 6 | S | S | S | S |
| Heligan | 5 | S | S | S | S |
| Muscat | 5 | S | S | S | S |
| Carat | 5 | S | S | S | S |
| Sequel | 5 | S | S | S | S |
| Sumo | 5 | S | S | S | S |
| Leonie | 4 | S | S | S | S |
| Siberia | 4 | S | S | S | S |
| Vanessa | 3 | S | S | S | S |
| Whisper | 3 | S | S | S | S |
| Regina | 2 | S | S | S | S |
| Diamond | 8 | S | S | R | S |
| Jewel | 8 | S | S | R | S |
| Scylla | 6 | S | S | R | S |
| Manitou | 5 | S | R | R | S |
| Pastoral | 9 | R | S | S | S |
| Gleam | 7 | R | S | S | S |
| Saigon | 6 | R | S | S | S |
| Antelope | 6 | R | S | S | S |
| Intro | 5 | R | S | S | S |
| Kestrel | 3 | R | S | S | S |
| Swallow | 7 | R | R | S | S |
| Cannock | 8 | R | S | R | S |
| Parasol | 9 | R | R | R | R |
| Differential / additional cultivars | | | | | |
| Berac | BYR0 | S | S | S | S |
| Astrix | BYR1 | R | R | S | S |
| Atem | BYR1 | R | R | S | S |
| Mazurka | BYR2 | R | R | S | S |
| Varunda | BYR2 | R | R | R | S |
| Bigo | BYR2 | R | R | R | S |
| Triumph | BYR3 | R | S | S | S |
| Optic | Rx | R | R | R | R |
| Derkado | R | R | R | R | R |

* based on reaction of differential cultivars in this test

** HGCA disease resistance rating

## CONCLUSIONS

Yellow rust of barley was more widespread in 2002 than since the 1980s. The recent popularity of highly susceptible winter barley cultivars is an obvious contributory factor. There is evidence of pathogenic variation within the UK yellow rust population that is not adequately described by the traditional differential cultivars. UK winter barley cultivars differ widely in partial resistance and there are indications of variation in specific resistance.

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## BROWN RUST OF WHEAT

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Resistance conferred by genes Lr9, Lr19 and Lr24 remains effective. Virulence to Thatcher backcross line Lr28, which was at a greatly increased frequency in 2001, was found at a similar level in the 2002 isolates. Cultivars Robigus and Tybalt were highly resistant as seedlings to the 2002 isolates. Field tests showed that one isolate, WBRS-01-04, carried increased virulence to cvs Buchan and Access, which carry gene Lr37, but that other Lr37 cvs remained resistant. There was no evidence of increased virulence to Lr37 in the samples received from the 2002 survey. A large number of the current winter and spring wheats are highly resistant.

## INTRODUCTION

Glasshouse tests in 2001 with an isolate cultured from cv. Buchan (Lr26, Lr37) showed increased virulence to some cvs postulated as carrying the resistance gene Lr37. This gene, whose resistance has remained effective to date, is thought to be deployed in several of the current HGCA Recommended List winter wheats and which occupied in excess of 12% of the winter wheat hectarage in 2002 (NIAB certified seed data, 2002). It may also be deployed in other current cvs as well as potential new cvs. There is little evidence from the samples received in 2002 that virulence to Lr37 is present in the pathogen population: only 1 sample was received from a cv. thought to carry this resistance gene and disease levels in the crop of origin, cv. Phlebas, were very low.

The 19 samples received were from winter wheats (Table 1). Four were from cv. Claire which occupies around 20% of the wheat area sown and which has shown high levels of resistance. One of the cv. Claire samples, from Lincolnshire, was from a crop assessed as having 5% of its flag leaf area infected. The other 3 samples were infected at much lower levels.

**Table 1** Source cultivars of 2002 wheat brown samples

| Cv. [1-9 rating] | No. of samples | Cv. | No. of samples | Cv. | No. of samples |
|---|---|---|---|---|---|
| Claire [8] | 4 | Phlebas | 1 | Charger [5] | 1 |
| Consort [4] | 3 | Tanker [6] | 1 | Solstice [5] | 1 |
| Hereward [7] | 2 | Riband | 1 | Option [5] | 1 |
| Arran | 1 | Soissons [3] | 1 | Shamrock [4] | 1 |
| Tellus | 1 | | | | |

[ ] 1-9 rating: 1 = susceptible, 9 = resistant

All samples were from East/South East England, with 12 from a trial site at NIAB, Cambridge. The others were from Cambridgeshire (2), Lincolnshire (2), Kent (2) and Suffolk (1).

## GLASSHOUSE SEEDLING TESTS WITH YEAR 2002 ISOLATES

### Methods

Isolates of *Puccinia recondita* were cultured from fourteen of the samples and tested on three sets of wheat lines: 1) differential cvs which comprise the standard WBR cvs (Table 2); 2) the core set of 'Thatcher' Near Isogenic Lines (NIL) carrying different Lr resistance factors (Table 3); 3) a number of potential new winter and spring wheat cvs (Table 4).

**Table 2** * Standard WBR cvs used in tests with 2002 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 3** 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 4** Newly introduced and potential new winter and spring* wheat cvs included in tests with isolates from the 2002 survey

| | | |
|---|---|---|
| CPBT W87 | SW Tataros | Vector |
| Nijinsky | Dick | Welbra |
| NSL WW47 | Robigus | Welford |
| Bentley | Einstein | Heritage |
| Smuggler | Tellus | *Belvoir |
| Wizard | Gladiator | *Tybalt |
| CPBT W83 | CPBT W90 | |
| Dart | Steadfast | |

Plants were grown in a spore-proofed glasshouse and, following inoculation, were placed in dew simulation chambers at 15°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).

## Results

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. Several of the cvs/lines expressed a mixture of resistant and susceptible infection types to the isolates making classification as susceptible or resistant difficult.

Virulence was identified to four of the standard differential cvs (Table 5) including the susceptible check cv. Armada (WBV-0)

**Table 5** Virulence frequencies corresponding to WBR formats present in differential cvs 1993-2002

| Cv. | WBR factor | Frequency† | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1993 | 1994 | 1995 | 1998 | 1999 | 2000 | 2001 | 2002 |
| Clement | 1 | 0.87 | 0.67 | 0.55 | 0.43 | 0.27 | 0.82 | 1.00 | 0.84 |
| Fundin* | 2 | 0.83 | 0.64 | 0.67 | 0.75 | 0.32 | 0.60 | 0.94 | 0.56 |
| Sappo* | 3 | 0.08 | 0 | 0 | 0 | 0 | 0.08 | 0 | 0 |
| Halberd* | 4 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 |
| Sterna* | 7 | 0.04 | 0.08 | 0.11 | 0.07 | 0 | 0.61 | 0.65 | 0.50 |
| Armada | 0 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| Number of isolates tested | | 53 | 39 | 18 | 43 | 22 | 23 | 17 | 14 |

†Only 1 and 4 isolates were tested in 1996 and 1997, respectively and these data are excluded
*Temperature-sensitive resistance

WBV-1 remains at a high frequency in the population. The corresponding resistance WBR-1 (gene Lr26) is carried in several of current HGCA Recommended List winter wheat cvs which occupied in excess of 18% of the wheat hectarage in 2002 (NIAB certified seed data 2002). Virulence to cv. Fundin (WBR-2), which carries gene Lr17b, was at a lower frequency than in 2001 but was still identified in 56% of the isolates. WBR-2 is a temperature-sensitive resistance which is more effective against some isolates at higher temperatures. Only cv. Riband of current cvs is thought to carry Lr17b. WBV-7 was found in half of the 2002 isolates, this virulence having increased in frequency in 2000. This was due to the popularity of cv. Chablis (WBR-7) which occupied 28% of the spring wheat hectarage in that year (5.6% in 2002) and the spring wheat cv. Shiraz which occupied 4% (30% in 2002). Both cvs are postulated as carrying Lr3a (Singh *et al.*, 2001) but cv. Shiraz has consistently expressed greater resistance as a seedling and adult plant.

Five different WBV-groups were identified (Table 6).

**Table 6** Virulence combinations and their frequencies identified from 2002 isolates compared with 1993-2002

| | Frequency | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| WBV formula | 1993 | 1994 | 1995 | 1998 | 1999 | 2000 | 2001 | 2002 |
| 0 | 0.04 | 0.30 | 0.22 | 0.18 | 0.50 | 0.18 | 0 | 0.14 |
| 1 | 0 | 0.03 | 0.11 | 0.05 | 0.18 | 0.09 | 0.06 | 0.22 |
| 2 | 0.09 | 0 | 0.22 | 0.37 | 0.23 | 0 | 0 | 0 |
| 7 | 0 | 0.03 | 0 | 0.02 | 0 | 0 | 0 | 0 |
| 1,2 | 0.75 | 0.58 | 0.34 | 0.33 | 0.09 | 0.04 | 0.29 | 0.14 |
| 1,3 | 0.02 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,7 | 0 | 0 | 0 | 0 | 0 | 0.09 | 0 | 0.07 |
| 1,2,7 | 0.04 | 0.06 | 0.11 | 0.05 | 0 | 0.52 | 0.65 | 0.43 |
| 1,2,3 | 0.06 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1,2,3,4 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 |
| 1,3,4 | 0 | 0 | 0 | 0 | 0 | 0.04 | 0 | 0 |
| Number of isolates tested | 53 | 39 | 18 | 43 | 22 | 23 | 17 | 14 |

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

WBV-1,2,7 was again the dominant form, having increased in frequency in recent years. This corresponds to the increased frequency of WBV-7 which has combined with previously dominant WBV-1,2.

Virulence frequencies in the 2002 isolates corresponding to each Thatcher-Lr backcross line are given in Table 7 where they are compared against the previous four years.

No isolate was able to infect Lr1, Lr2a, Lr2b, Lr2c and Lr23 at both temperatures although some isolates gave a susceptible reaction on one or more of these lines at one or other of the two test temperatures. Virulence to Lr2a and Lr2b has been identified previously but their resistances were effective at 25$^{o}$C to the 2002 isolates. The resistance genes Lr9, Lr19 and Lr24 were again effective at 10$^{o}$C and 25$^{o}$C to all isolates. Line Lr21, virulence to which was at an unusually high level in 2001, was resistant to the 2002 isolates. Fewer isolates (29%) overcame the resistance of Lr3 than cv. Sterna (WBR-V) which carries this gene. This difference is probably due to the range of infection types expressed by this line and cv. Sterna

to several of the isolates which made classification as susceptible or resistant difficult. Similarly frequencies of virulence to Lr17 and cv. Fundin (WBR-2) did not concur. However, Line Lr26 and cv. Clement (WBR-1) were susceptible to the same 12 isolates.

**Table 7** Virulence frequencies corresponding to each Thatcher-Lr backcross line for years 1998-2001

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

The only other Thatcher-backcross lines susceptible to some isolates at both 10°C and 25°C were Lr11, Lr15 and Lr28. Virulence to Lr28 was at an increased frequency in 2001 and was at a similar level in 2002. This increased frequency is difficult to explain as none of the current UK wheat cvs are thought to carry Lr28. Virulence to this gene did, however, fluctuate between years in some European countries during the period 1996-1999 (Mesterházy *et al.*, 2000). Overall individual virulences to the Thatcher-Lr backcross lines were generally at lower levels than in 2001, when they were at an increased frequency.

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

1. Cultivars Steadfast, CPBT W90, Welford, Welbra, Vector and Gladiator were susceptible to isolates virulent on Lr26 but resistant to those lacking virulence to this gene.

2. Cultivars Robigus, Tybalt and Belvoir were resistant at both temperature regimes, although in cv. Belvoir the reaction was of a mixed type at 25°C. Cultivar Dart was also resistant but showed a mixed susceptible reaction to some isolates at 10°C.
3. Cultivars Wizard, NSL WW47 ,CPBT W87 and Heritage were susceptible at 10°C but resistant (mixed reaction) to some or all the isolates at 25°C
4. Cultivars Einstein, Dick, SW Tataros, CPBT W83 and Tellus were susceptible to all the isolates at both temperatures.
5. Cultivars Smuggler and Nijinsky expressed very mixed reactions to all the isolates.

## ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

### Methods

Winter and spring wheat cvs, including those on the HGCA Recommended Lists, potential new cvs, outmoded cvs, the standard differential cvs and cv. Thatcher backcross lines carrying different Lr resistance genes, were sown in each of three nurseries. The nurseries were inoculated with one or other of the following isolates:

| | |
|---|---|
| WBRS-01-14 (*WBV-1,2) | ex cv. Tanker, South Glamorgan |
| WBRS-01-04 (*WBV-1,2,7) | ex cv. Buchan, Cambridge |
| WBRS-01-16 (*WBV-1,2,7) | ex cv. Paragon, Suffolk |

*Virulence factors identified in seedling tests.

Isolate WBRS-01-14 was sampled from a crop of cv. Tanker which had infection levels of 20% *in foci*. This cv. had previously shown good levels of field resistance and had a 1-9 disease rating of 8. This rating has subsequently been lowered to 6.

Isolate WBRS-01-04 infected seedlings of a number of previously resistant cvs in 2001 controlled environment tests (Jones, 2002). These included some cvs carrying Lr37, a resistance gene deployed in many of the current cvs and whose resistance has been very effective. Also it overcame the adult plant resistance of the Thatcher backcross line Lr37.

Isolate WBRS-01-16 was from a crop of cv. Paragon, described as being 'quite severely' infected. This spring wheat has previously shown high levels of resistance and has a very resistant disease rating of 9. In controlled environment tests in 2002 the temperature-sensitive resistance of cv. Paragon was effective against isolate WBRS-01-16 at 10°C.

## Results

### Winter Wheats (Table 8)

Disease levels on the susceptible cvs were not the same across the three nurseries. This was probably due to favourability between locations with respect to the development of disease during a prolonged period of windy, dry weather, and consequently lack of dews, during late spring.

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

1) European ring tests between 1996 and 1999 and additional seedling tests at the Plant Breeding Institute, Cobbitty, Australia (Winzeler, Mesterházy and Park *et al.*, 2000). Also seedling and adult plant tests at the same institute (Singh, Park and McIntosh, 2001).

2) Association with stripe rust resistance (WYR) factors (Bayles and Stigwood, 2000, 2001; Bayles, Slater and Hopkins, 2002).

The newly introduced cvs Robigus and Wizard were free from infection. Cultivars postulated as carrying Lr genes 10, 26 and 37 were resistant except for cv. Access which was susceptible to, and relatively highly infected by, isolate WBRS-01-04. Cultivars Buchan and Savannah which lack Lr10 but carry genes Lr26 and Lr37 were, like cv. Access, susceptible to isolate WBRS-01-04. Cultivar Biscay also postulated as carrying Lr26 and Lr37 was, however, resistant suggesting that it carries additional resistance. It may be that Lr10 is conferring this increased resistance as it may also be in cvs Equinox, Phlebus and Madrigal. However, this is unlikely as virulence to Lr10 appears to be common in Europe. Also cvs Consort and Charger, both of which carry Lr10 in combination with Lr13, were heavily infected.

A number of cvs including Claire and Hereward were infected at low levels although they were more heavily infected in NIAB, Cambridge field tests (J. Clarkson, NIAB, pers. comm.). In fact, the majority of cvs showed much higher levels of disease in NIAB field tests with the exception of that group comprising mainly Lr37 cvs. Those showed higher levels of infection at IGER, Aberystwyth, to one isolate, WBRS-01-04, which was not included in NIAB tests. This suggests that this isolate does, as suspected from some cv./isolate interactions in 2001 controlled environment tests, carry increased virulence to some Lr37 cvs.

### Spring Wheats (Table 9)

The spring wheat cvs were mostly highly resistant. Cultivar Chablis (WBR-7) which carries Lr3 was infected at low levels although the Thatcher backcross line Lr3 was heavily infected. Cultivar Chablis does, however, carry additional adult plant resistance. Some of the cvs

including Paragon showed slightly higher, but still low, disease levels to isolate WBRS-01-16 which originated from a crop of cv. Paragon.

The Thatcher Lr-backcross lines Lr9, Lr17, Lr19 and Lr24 were resistant as they have been in similar tests to different isolates in previous years. Also resistant was line Lr20, this gene being carried by the differential cvs Sappo (WBR-3) and Halberd (WBR-4) which were also resistant. Virulence to this resistance has remained at a low frequency in the pathogen population.

Line Lr13 was susceptible. Several European and some UK cvs carry gene Lr13 which on its own is generally ineffective in conferring resistance, e.g. cv. Huntsman. However, in combination with other genes it can be effective, e.g. Hereward. Line Lr28, which prior to 2001 had shown good field resistance, was highly susceptible to isolates WBRS-01-14 and WBRS-01-04. As mentioned previously virulence to Lr28 was identified at an increased frequency in the 2001 and 2002 isolates, although the reasons for this are difficult to explain.

Previously line Lr37, whose resistance is temperature-sensitive, has expressed low levels of a mixed, mainly resistant infection type in field nurseries to all but one isolate. This isolate, WBRS-98-20, infected it at much higher levels but again the infection type was predominantly resistant. The three isolates in 2002 tests, however, induced a mixed, mainly susceptible infection type, although disease levels were relatively low. It appears that there is some breakdown in the resistance of line Lr37 and that some cvs postulated as carrying this gene are showing increased susceptibility. However, infection levels are still relatively low on these cvs and of a mixed infection type. Also no samples were received in 2002 from cvs carrying Lr37.

## CONTROLLED ENVIRONMENT TESTS

### Methods

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

| | | |
|---|---|---|
| WBRS-01-04 | (WBV-1,2,7) | ex. cv. Buchan, Cambridgeshire |
| WBRS-02-15 | (WBV-1,2) | ex. cv. Claire, Lincolnshire |
| WBRS-02-12 | (WBV-0) | ex. cv. Shamrock, Cambridgeshire |

Isolate WBRS-01-04 was introduced into a 2002 field nursery and is described earlier.

Isolate WBRS-02-15 was from a crop of cv. Claire which was assessed as having 5% of its flag leaf area infected.

Isolate WBRS-02-12 cultured from a crop of the susceptible cv. Shamrock (1-9 disease resistance rating of 4) did not carry virulence to any of the standard differential cvs in seedling tests.

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

## Results (Table 10)

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). Cultivars are grouped within the table on the basis of similarities in their interactions with the isolates.

**Group 1:** Cultivar are highly resistant.
**Group 2:** Cultivars were resistant at 10°C. At 25°C the spring wheat cvs Paragon, Shiraz, Wallace and Morph were susceptible to isolate WBRS-01-04 and WBRS-02-15 but resistant to the 'simpler' isolate WBRS-02-12. Cultivar Belvoir differed from the other spring wheats in that it was also susceptible to isolate WBRS-02-12 at the higher temperature. The winter cvs Wizard and Richmond expressed a mixed, mainly susceptible infection type to isolate WBRS-01-04 but a more resistant response to the other isolates. Cultivar Chatsworth was resistant to the isolates at both temperature regimes.
**Group 3:** The resistance of cv. Claire was effective against isolates WBRS-01-04 and WBRS-02-12, but it did express a susceptible reaction to the 'Claire' isolate (WBRS-02-15). However, disease levels were low (3%) and the adult plant resistance of this cv. appears to remain effective.
**Group 4:** This group comprises cvs postulated as carrying gene Lr37. Cultivars Buchan and Access were susceptible to isolate WBRS-01-04 as they were to the same isolate in a 2002 field nursery. Cultivar Napier, which displayed a more resistant reaction in the field, was also more resistant at 25°C in controlled environment tests. Although the Thatcher backcross line Lr37 was quite heavily infected, it was of a mixed, mainly resistant type. It showed a more susceptible response to the same isolate in similar tests in 2001.
**Group 5:** Infection levels on line Lr26 were much lower on those plants inoculated with isolate WBRS-02-12 which was not identified as carrying the corresponding virulence in seedling tests. Cultivar Tanker likewise carries gene Lr26 but has additional adult plant resistance which was effective against isolate WBRS-02-15.
**Group 6:** This group comprises line Lr10, susceptible to the three isolates but more heavily infected by isolate WBRS-01-04; line Lr13 whose temperature-sensitive resistance was effective at 25°C, and cv. Solstice which has a disease resistance rating of 5 but was infected at relatively low levels at 10°C.

## NOTE

Gene Lr37, often in combination with Lr10 and/or Lr26, has conferred effective resistance in a number of UK and European winter wheats. Virulence to Lr26 is at a high frequency in the pathogen population whilst Lr10 appears to offer little protection in the field. The resistance of these cvs is therefore dependent on the adult plant resistance of Lr37 remaining effective. One isolate carried increased virulence to some cvs postulated as carrying Lr37 in 2001

controlled environmental tests and these cvs were also more susceptible in a 2002 field nursery artificially inoculated with the same isolate. Although there were no reports of increased virulence to Lr37 cvs grown in the UK in 2002, it appears that there may be increased virulence to one such cv. in France (Henriette Goyeau, pers. comm.). It is important therefore that Lr37 cvs are monitored for increased susceptibility. This will require greater resources to be put into adult plant testing.

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**Table 8** †Reaction of winter wheat cvs to specific isolates of *Puccinia recondita* in field isolation nurseries in 2002

| | | | | ISOLATE | | |
|---|---|---|---|---|---|---|
| Cultivar [1-9 rating] | WBR- | Postulated Lr genes | ▪Resistance type | WBRS-01-14 (WBV-1,2) | WBRS-01-04 (WBV-1,2,7) | WBRS-01-16 (WBV-1,2,7) |
| Clement | 1 | 26 | OR | 23 | 13 | 1 |
| Fundin | 2 | 17b | OR* | 26 | 13 | 5 |
| Huntsman | 5 | 13 | APR | 30 | 12 | 4 |
| Gamin | 6 | | APR | 13 | 4 | 2 |
| Sterna | 7 | 3a+APR | OR*+APR | 2 | 8 | 0.4 |
| Sabre | 7 | 3a+APR | OR*+APR | 6 | 12 | 0.3 |
| Ranger | 8 | | APR | 0 | 0 | 0.1 |
| Avalon | 9 | | APR | 23 | 19 | 10 |
| Arina | 0 | 13 ? | | 43 | 23 | 14 |
| | | | | | | |
| Robigus [9] | | | OR | 0 | 0 | 0 |
| Wizard [9] | | | OR | 0 | 0 | 0 |
| Equinox [9] | | (10,26,37) | OR | 0 | 0 | 0 |
| Phlebas | | (10,26,37) | OR | 0 | Tr | 0 |
| Madrigal [9] | | (10,26,37) | OR | Tr | Tr | 0 |
| Macro | | | OR | Tr | 0.5 | 0 |
| Goodwood | | | OR* | 0.7 | 0.1 | 0 |
| Napier [9] | | (10,26,37) | OR* | 0.2 | 8 MR | Tr MS |
| Access [9] | | (10,26,37) | OR | 3 MS | 12 MS | 0.1 |
| Biscay [9] | | (26,37) | OR | 0 | 0 | 0 |
| Savannah [8] | | (26,37) | OR | Tr | 7 | Tr |
| Buchan [9] | | (26,37) | OR* | 1 | 10 MS | 0.2 |
| Brunel | | | OR* | 1 | 6 MS | 0 |
| | | | | | | |
| Claire [8] | | | APR | 0.2 | Tr | Tr |
| Chatsworth | | | * | 4 MS | Tr | Tr |
| Richmond [9] | | | OR* | 3 MS | Tr | Tr R |
| Hereward [7] | | 13+APR | OR | 0.4 | 1 | 1 |
| NSL WW37 | | | OR* | Tr | 0.9 | 3 |
| Scorpion 25 [6] | | | OR* | 3 | 0.4 | 2 |
| Warlock 24 | | | OR* | 5 | 0.4 | 0.8 |
| Malacca [7] | | | APR | 4 | 2 | 1 |
| Xi 19 [6] | | | OR* | 7 | 0.4 | 1 |
| Deben [5] | | | OR* | 4 | 7 | 2 |
| Einstein [5] | | | OR* | 2 | 4 | 6 |
| Arran | | | OR* | 6 | 9 | 3 |
| Shamrock [4] | | | APR | 4 | 7 | 8 |
| Charger [5] | | 10,13 | * | 2 | 18 | 5 |
| Consort [4] | | 10,13 | APR | 10 | 18 | 13 |
| Riband [3] | | 13,17b | * | 13 | 20 | 5 |
| Option [5] | | | * | 17 | 6 | 5 |
| Carlton | | | | 17 | 15 | 1 |
| Tanker [6] | | 26+ | OR | 23 | 15 | 0.5 |
| Solstice [5] | | | * | 30 | 10 | 2 |
| Soissons [3] | | | APR | 17 | 27 | 4 |

†Mean of 3 replicates, 2 assessment dates. All reaction types susceptible unless stated.
R = resistant; MR = mixed resistant; MS = mixed susceptible
APR = adult plant resistance; OR = overall resistance; * temperature sensitive resistance.
( ) postulated Lr genes based on links to resistances for stripe rust.
[ ] Resistance rating: 1 = susceptible; 9 = resistant ▪resistance type from past performance

**Table 9** †Reaction of spring wheat cvs and Thatcher Lr backcross lines to specific isolates of *Puccinia recondita* in field isolation nurseries in 2002

| | | | | ISOLATE | | |
|---|---|---|---|---|---|---|
| Cultivar [1-9 rating] | WBR- | Postulated Lr genes | ▪Resistance type | WBRS-01-14 (WBV-1,2) | WBRS-01-04 (WBV-1,2,7) | WBRS-01-16 (WBV-1,2,7) |
| Sappo | 3 | 20 | OR* | Tr | Tr | 0 |
| Halberd | 4 | 20 | OR* | Tr | | Tr |
| | | | | | | |
| Status | | | OR | 0 | 0 | 0 |
| Morph [8] | | | * | 0 | 0 | 0 |
| Belvoir [9] | | | OR* | 0 | 0 | 0 |
| Tybalt | | | OR | 0 | 0 | 0 |
| Wallace [8] | | | * | 0 | 0 | 0.1 |
| Paragon [9] | | | APR* | 0 | 0 | 2 |
| Shiraz | | 3a+23 | OR+APR* | 0 | 0 | 0 |
| Alder | | | OR* | Tr | Tr | 0.4 |
| Ashby [8] | | | OR* | Tr | 0.1 | 0.4 |
| Ambient [8] | | | OR* | Tr | 0.2 | 0.6 |
| Imp [5] | | | APR* | 0.5 | 0.2 | 1 |
| Chablis [6] | | 3a+APR | OR*+APR | 3 MS | 3 | 0.3 |
| | | | | | | |
| Lr1 | | | | 6 | 12 | 6 |
| Lr2a | | | | 15 | 18 | 17 |
| Lr2b | | | | 25 | 23 | 22 |
| Lr2c | | | | 23 | 30 | 25 |
| Lr3 | | | | 38 | 45 | 15 |
| Lr9 | | | | 0 | 0 | 0 |
| Lr11 | | | | 25 | 20 | 18 |
| Lr13 | | | | 16 | 22 | 17 |
| Lr14a | | | | 40 | 37 | 17 |
| Lr15 | | | | 27 | 30 | 15 |
| Lr17 | | | | 17 MR | 16 MR | 10 MR |
| Lr19 | | | | Tr | 1 MS | Tr |
| Lr20 | | | | Tr | 1 | 0 |
| Lr21 | | | | 21 | 13 | 11 |
| Lr23 | | | | 9 MS | 13 MS | 5 MS |
| Lr24 | | | | 0 | 0 | 0 |
| Lr26 | | | | 33 | 33 | 7 |
| Lr28 | | | | 38 | 30 | 4 |
| Lr37 | | | | 6 MS | 5 MS | 1 MS |

†Mean of 3 replicates, 2 assessment dates. All reaction types susceptible unless stated.
R = resistant; MR = mixed resistant; MS = mixed susceptible
APR = adult plant resistance; OR = overall resistance; * temperature sensitive resistance.
( ) postulated Lr genes based on links to resistances for stripe rust.
[ ] Resistance rating: 1 = susceptible; 9 = resistant ▪resistance type from past performance

**Table 10** Percentage area of *flag leaf infected and †reactions 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-01-04 ▪(WBV-1,2,7) 10°C | WBRS-01-04 ▪(WBV-1,2,7) 25°C | WBRS-02-15 ▪(WBV-1,2) 10°C | WBRS-02-15 ▪(WBV-1,2) 25°C | WBRS-02-12 ▪(WBV-0) 10°C | WBRS-02-12 ▪(WBV-0) 25°C |
|---|---|---|---|---|---|---|---|---|
| Status | | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Tybalt | | | 0 | 0 | 0 | 0 | 0 | 0 |
| Robigus [9] | | | 0 | 0 | 0 | 0 | 0 | 0 |
| Biscay | | | 0 | 2 R | 0 | 0.5 R | 0 | 1 R |
| Goodwood | | | 0 | 0 | 1 | 1 R | 0 | 0 |
| Wizard [9] | | 2 | 0 | 15 MS | 0 | 15 MR | 0 | Tr |
| Richmond [9] | | | 0 | 20 MS | 0.1 | 2 MS | 0 | 2 MR |
| Chatsworth | | | 15 R | 40 MR | 3 R | 10 MR | 0 | 10 MR |
| Paragon [9] | | | 0 | 20 | 0 | 25 | 0 | 15 MR |
| Shiraz | 3a,23 | | 15 R | 15 | 0 | 15 | 0 | 0.2 R |
| Wallace | | | 10 R | 25 | 10 R | 15 | 0 | 25 MR |
| Morph [8] | | | 20 MR | 15 MS | 0 | 20 | 0 | 1 |
| Belvoir [9] | | | 15 R | 15 | 0 | 20 | 0 | 20 |
| Claire [8] | | 3 | 0 | 40 MR | 3 | 3 | 0 | 20 R |
| Lr37 | | 4 | 25 MR | 25 | 3 R | 25 | 5 MR | 10 MR |
| Buchan [9] | 26,37 | | 15 MS | 20 | 1 | 5 MR | 1 | 5 R |
| Access [9] | 10,26,37 | | 10 | 20 | 5 | 10 MR | 0 | 0 |
| Napier [9] | 10,26,37 | | 10 | 20 MR | 5 | 3 R | 3 | 0.5 MR |
| Lr26 | | 5 | 30 | 35 | 10 | 15 | 3 | 3 |
| Tanker [6] | 26+ | | 20 | 20 | 3 | 15 MR | 1 | 20 MR |
| Lr10 | | 6 | 50 | 25 | 10 | 10 | 5 | 10 |
| Lr13 | | | 30 | 10 MR | 10 | 25 MR | 5 | 10 MR |
| Solstice [5] | | | 5 | 20 MS | 8 | 30 MS | 10 | 25 MS |

*Mean of 2 replicates.
†reaction types assessed on a 0-4 scale. Resistant (R: 0-2); Susceptible (S: 3-4)
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.
[ ] resistance rating: 1 = susceptible; 9 = resistant

# BROWN RUST OF BARLEY

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Race octal 273 (BBV1,2,4,6,8,9) which increased in frequency in the mid 1990s was the dominant pathotype. Isolates classified as race octal 273 often overcame the resistance/s of some winter barley cvs which are effective to pathotypes carrying additional virulence factors. Some of these cvs were also more susceptible in the field in 2002 to race octal 273 than they had been in previous years to more complex races. The HGCA Recommended List cvs Kestrel, Angela, Sumo and Haka expressed good levels of adult plant resistance. The potential new cvs NSL 98-6329C, Aquarelle and Nocturne were the only winter barleys to carry seedling resistance. Cv/isolate interactions suggest that they carry one or more of resistance factors BBR-3, BBR-9 and BBR-10. Increased seedling virulence to the spring barley cvs Adonis, Cellar, County, Static and Tavern was not confirmed at later growth stages in the field.

## INTRODUCTION

Brown rust-infected leaf samples were received from crops of 78 winter and 7 spring barleys (Table 1). Some winter barley crops were reported as heavily infected although these were of susceptible cvs with HGCA disease ratings of 5 to 6. Where the information was provided, generally low levels of disease were present in cvs with higher (more resistant) disease ratings, e.g. cvs Haka and Leonie. Fifty nine of the samples were from Cambridgeshire, mainly NIAB trial sites. The remainder were collected across 16 English counties from Cornwall to North Yorkshire.

## SEEDLING TESTS WITH 2002 ISOLATES

### Methods

Isolates cultured from 33 samples were tested on the standard set of 10 cvs listed in Table 2 and also on the spring barley cvs Static, County, Tavern and Cellar which have previously expressed high levels of resistance but whose BRR characteristics are unknown.

**Table 1** Source cvs of 2002 brown rust samples

| Barley cv. | No. of samples | Barley cv. | No. of samples | Barley cv. | No. of samples |
|---|---|---|---|---|---|
| **Winter cvs** | 8 | Leonie | 3 | Pastoral | 1 |
| Pearl | 5 | Cannock | 3 | Muscat | 1 |
| Heligan | 4 | Saigon | 3 | Kestrel | 1 |
| Pict | 4 | Antelope | 2 | Parasol | 1 |
| Carat | 4 | Hanna | 2 | Angela | 1 |
| Sequel | 4 | Scylla | 2 | Unknown | 3 |
| Vanessa | 3 | Haka | 2 | **Spring cvs** | |
| Pedigree | 3 | Regina | 1 | Decanter | 2 |
| Clara | 3 | Fanfare | 1 | Pewter | 1 |
| Diamond | 3 | Antonia | 1 | Chalice | 1 |
| Opal | 3 | Sumo | 1 | Static | 1 |
| Siberia | 3 | Jewel | 1 | Global | 1 |
| Swallow | 3 | Vertige | 1 | Riviera | 1 |

**Table 2** Cultivars used to test BBR isolates

| 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 |
| Static | - | - | - |
| County | - | - | - |
| Tavern | - | - | - |
| Cellar | - | - | - |

## Results

BBV-1, BBV-2, BBV-4, BBV-6 and BBV-8 were carried by all the isolates (Table 3), BBV-10 first identified in 1981, and whose frequency increased rapidly due to the large area of spring barley sown to cv. Trumpf and its derivatives during the 1980s,

remains at a high frequency in the population. The reactions of a number of current spring barley cvs to pathotypes carrying a range of virulences suggest that BBR-10 is still being deployed but often in combination with other resistance/s. Very few cvs have relied solely on BBR-3 for resistance but the corresponding virulence, carried by 36% of the 2002 isolates, has remained at a fairly stable frequency over a number of years. As with BBR-10, it is probable that this resistance is combined with other resistances in some of the current spring barleys (e.g. cvs Static, Cellar, Tavern) as they appear less resistant to BBV-3 pathotypes. The frequency of BBV-5 also remains stable and at a high level although there is no evidence that the gene Rph5 has been carried by any commercially important cvs in recent years. As in previous years, no isolate overcame the resistance of Cebada Capa (BBR-7).

**Table 3** Frequencies of individual virulences 1992-2002

| | Frequency | | | | | |
|---|---|---|---|---|---|---|
| BRV - Year | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 |
| 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 | 0.08 | 0.33 | 0.42 | 0.23 | 0.50 | 0.36 |
| 4 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 5 | 0.71 | 0.75 | 0.84 | 0.96 | 0.83 | 0.82 |
| 6 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 7 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 | 1.00 |
| 9 | 1.00 | 1.00 | 0.58 | 0.33 | 0.83 | 0.68 |
| 10 | 0.98 | 0.75 | 0.50 | 0.45 | 0.83 | 0.68 |
| No. of isolates | 77 | 12 | 12 | 27 | 6 | 33 |

The pathotypes identified (Table 4) were complex, carrying between 6 (race octal 273) and 9 (race octal 1677) virulence factors. The dominant pathotype was race octal 273, as it has been since 1998 with the exception of year 2000 when sample numbers were very low. This race increased in frequency in the mid 1990s, having previously been identified only occasionally. It lacks virulence to BBR-3 and BBR10 but has consistently infected a number of winter barley cvs, e.g. Heligan, Antonia and Pearl, at higher levels than races carrying additional virulence factors in adult plant glasshouse tests (Jones, 2002).

**Table 4** Races and their frequencies identified from the 2002 isolates compared with representative data from the previous ten years

| Race Octal | BBV factors | Frequency | | | | | |
|---|---|---|---|---|---|---|---|
| | | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 |
| 273 | 1,2,4,5,6,8 | 0 | 0 | 0.34 | 0.44 | 0.17 | 0.28 |
| 673 | 1,2,4,5,6,8,9 | 0.2 | 0.17 | 0.08 | 0 | 0 | 0 |
| 277 | 1,2,3,4,5,6,8 | 0 | 0 | 0 | 0.11 | 0 | 0.04 |
| 677 | 1,2,3,4,5,6,8,9 | 0 | 0.08 | 0.08 | | 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 | 0.25 | 0.17 | 0.08 | 0 | 0 | 0.10 |
| 1657 | 1,2,3,4,6,8,9,10 | 0.04 | 0.08 | 0.08 | 0 | 0.17 | 0.10 |
| 1673 | 1,2,3,4,5,8,9,10 | 0.65 | 0.33 | 0 | 0.25 | 0.33 | 0.24 |
| 1677 | 1,2,3,4,5,6,8,9,10 | 0.04 | 0.17 | 0.26 | 0.08 | 0.33 | 0.24 |
| No. of isolates | | 77 | 12 | 12 | 27 | 6 | 33 |

## GLASSHOUSE SEEDLING TESTS WITH SPECIFIC ISOLATES OF BROWN RUST

### Methods

Seedlings of spring barley and potential new winter barley cvs were grown in a spore-proofed glasshouse to the second leaf stage. Each cv. was inoculated separately with each of the following isolates:

| Isolate | BBV- | Race octal | Origin |
|---|---|---|---|
| BRS-01-07 | 1,2,4,5,6,8 | 273 | cv. Jackpot, North Yorkshire |
| BRS-00-04 | 1,2,3,4,6,8,9,10 | 1657 | cv. Pearl, Lancashire |
| BRS-02-07 | 1,2,3,4,6,8,9,10 | 1657 | cv. Cannock, Cambridgeshire |

In previous seedling tests isolate BRS-02-07 was identified as carrying the same virulence factors as isolate BRS-00-04 but additionally gave a susceptible reaction (type 3) on seedlings of cvs Static, Tavern, Cellar and County. These cvs expressed a mixed mainly resistant reaction to BRS-00-04. Post-inoculation plants were placed in dew simulation chambers in the dark for 24 hours at 15$^{o}$C. They were then incubated in the glasshouse at approximately 15$^{o}$C for 14 days.

## Results

Cultivars were classified into groups (Table 5) on the basis of similarities in the pattern of their responses to the isolates. Grouping does not necessarily imply that cvs within a group carry a common resistance factor(s).

**Group 1:** Cultivars susceptible.
**Group 2:** Cultivars were resistant to isolate BRS-01-07 (race octal 273) but susceptible to the other isolates, although in cvs Adonis, Vortex and Sebastian the reaction to isolate BRS-00-04 was of a mixed, mainly susceptible type.
**Group 3:** Good levels of resistance have previously been shown by cvs within this group, although some isolates have infected them as seedlings (mixed, mainly susceptible reaction). One isolate, BRS-02-07, induced a fully susceptible infection type on the cvs, as it had done in previous seedling tests. The cvs were, however, resistant (mixed, mainly resistant reaction) to isolate BRS-00-04 which carries the same virulences as isolate BRS-02-07 based on the reactions of the 10 seedling differential cvs.
**Group 4:** Cultivar Quinn (BBR-5) was susceptible only to isolate BRS-01-07 (race octal 273) that carries the corresponding virulence, BBV-5.
**Group 5:** The winter barleys were susceptible to all three isolates. All winter barley cvs tested in recent years against isolates carrying a similar range of virulences have been seedling susceptible.
**Group 6:** The potential new winter cvs. NSL 98-6329C, Aquarelle and Nocturne were resistant to isolate BRS-01-07 (race octal 273), the 'simplest' pathotype. Some winter barley cvs have previously been more susceptible as seedlings and adult plants to isolates carrying this combination of virulences (BBV-1,2,4,5,6,8) than more complex pathotypes (Jones, 2002). Cultivar/isolate interactions in 2002 tests suggest that cvs within this group carry one or more of the resistance genes Rph3, Rph9 and Rph12.

## ADULT PLANT FIELD ISOLATION NURSERIES

## Methods

Winter and spring barleys were sown during the 2001-2002 season. They included cvs on the HGCA Recommended Lists of winter and spring barleys, some members of the standard set of differential cvs, outmoded cvs and potential new cvs. Spores of isolate BRS-01-07 (race octal 273), ex cv. Jackpot, North Yorkshire, were introduced artificially into the winter nursery. This isolate had infected a number of winter cvs which had been resistant to more widely virulent pathotypes in 2001 glasshouse tests. Cultivars within the spring barley nursery were inoculated with isolate BRS-01-02 (race octal 1657) ex cv. Siberia, Cambridge. Some spring barley cvs, including Static, Tavern and Cellar had, as seedlings, shown increased susceptibility to this isolate in 2001.
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

All cvs were classified as susceptible based on reaction types but they displayed a range in levels of susceptibility (Table 6). Cultivar Vertige, which has a disease resistance rating of 7, was the most susceptible although cvs with lower ratings (less resistant) were infected at lower levels. It was also among the most susceptible cvs in field tests in 2000 and 2001. A range of cvs have, in glasshouse adult plant tests, in recent years been more susceptible to isolate identified as race octal 273 (BBV-1,2,4,5,6,8) than to some pathotypes carrying additional virulences (Table 7). Also, some of these cvs have, when tested against more complex races in the field, been less susceptible than would be expected from their disease ratings, e.g. cvs Opal and Heligan (Jones, 2002). When exposed to race octal 273 in the 2002 field nursery, however, a few of these cvs showed greatly increased levels of infection (Table 6) thus confirming their glasshouse responses and in most instances their 1-9 disease resistance ratings.

**Table 7** Percent infection of winter barley cvs in a field isolation nursery in 2002 compared to previous two years

| Year<br>Cultivar<br>[1-9 rating] | | 2000<br>Race Mixture<br>(BBV-1,2,3,4,5,6,8,9,10) | 2001<br>Race octal 1677<br>(BBV-1,2,3,4,5,6,8,9,10) | 2002<br>Race octal 273<br>(BBV-1,2,4,5,6,8) |
|---|---|---|---|---|
| Opal | [5] | 11 | 2 | 24 |
| Diamond | | - | 2 | 21 |
| Heligan | [6] | 7 | 2 | 28 |
| Pearl | [6] | 0.5 | 2 | 10 |
| Antonia | [7] | 1 | 2 | 6 |
| Haka | [8] | - | 0.2 | 4 |
| Sumo | [6] | 0.5 | 2 | 4 |
| Vanessa (susc. check) | | 20 | 13 | 28 |

It appears therefore that a number of winter barley cvs are more susceptible to isolates identified as race octal 273, which has increased in frequency in recent years, than to some more complex pathotypes.

### Spring barleys (Table 8)

High levels of disease built up on the susceptible spring barley cvs in a season conducive to the development of the disease. Cultivars expressed a range of quantitative, susceptible or resistant responses to the introduced pathotype, with cv. rankings generally confirming their 1-9 disease ratings. Some of the resistant cvs, namely Cellar, Static, Tavern, County and Adonis, had been susceptible to isolate BRS-01-02 in glasshouse seedling tests. The seedling differential cv. Quinn (BBR-5) was susceptible

although it had been resistant in seedling tests thus suggesting contamination of the nursery with endemic pathotypes.

## ACKNOWLEDGEMENTS

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## REFERENCE

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**Table 5** Seedling *reactions of spring barley cvs, and potential new winter barley cvs to specific isolates of *Puccinia hordei*

| Isolate<br>Cv. | Group | BRS-01-07<br>(BBV-1,2,4,5,6,8)<br>Race octal 273 | BRS-02-07<br>(BBV-1,2,3,4,6,8,9,10)<br>Race octal 1657 | BRS-00-04<br>(BBV-1,2,3,4,6,8,9,10)<br>Race octal 1657 |
|---|---|---|---|---|
| Spring Barley | | | | |
| Pewter | 1 | S | S | S |
| Riviera | | S | S | S |
| Chalice | | S | S | S |
| Novello | | S | S | S |
| Cocktail | | S | S | S |
| Troon | | S | S | S |
| Kirsty | 2 | R | S | S |
| Global | | R | S | S |
| Decanter | | R | S | S |
| Colston | | R | S | S |
| Optic | | R | S | S |
| Spire | | R | S | S |
| Vortex | | R | S | S |
| Adonis | | R | S | MS |
| Topic | | R | S | MS |
| Sebastian | | R | S | MS |
| Simon (BBR-3) | | R | S | S |
| Trumpf (BBR-10) | | R | S | S |
| Tavern | 3 | R | S | MR |
| Static | | R | S | MR |
| County | | R | S | MR |
| Cellar | | R | S | MR |
| Quinn (BBR-5) | 4 | S | R | R |
| Winter barley | | | | |
| Pedigree | 5 | S | S | S |
| Clara | | S | S | S |
| Antelope | | S | S | S |
| Swallow | | S | S | S |
| Wigwam | | S | S | S |
| Eden | | S | S | S |
| Camion | | S | S | S |
| Tallica | | S | S | S |
| Connoisseur | | S | S | S |
| Colossus | | S | S | S |
| NSL 98-6329C | 6 | R | S | S |
| Aquarelle | | R | S | S |
| Nocturne | | R | S | S |

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

**Table 6** *Reactions of winter barley cultivars to brown rust in a field nursery in 2002

| Cultivar [1-9 rating] | % Infection | Reaction type |
|---|---|---|
| Vertige [7] | 36 | S |
| Cannock [4] | 35 | S |
| Carat [4] | 30 | S |
| Vanessa [3] | 28 | S |
| Heligan [5] | 28 | S |
| Leonie [6] | 26 | S |
| Antelope | 25 | S |
| Saigon | 25 | S |
| Opal [5] | 24 | S |
| Siberia [5] | 23 | S |
| Pastoral [6] | 23 | S |
| Jewel [6] | 22 | S |
| Diamond [7] | 21 | S |
| Regina [7] | 21 | S |
| Swallow | 17 | S |
| Sequel [5] | 17 | S |
| Clara | 16 | S |
| Parasol | 11 | S |
| Pearl [6] | 10 | S |
| Muscat [6] | 9 | S |
| Pict [6] | 9 | S |
| Scylla [6] | 9 | S |
| Pedigree | 7 | S |
| Antonia [7] | 6 | S |
| Fanfare [7] | 6 | S |
| Kestrel [8] | 5 | S |
| Haka [8] | 4 | S |
| Sumo [7] | 4 | S |
| Angela [8] | 2 | S |

*Mean of 4 replicates, final assessment date
S = susceptible (3-4 type reaction)
[ ] Resistance rating : 1 = susceptible ; 9 = resistant

**Table 8** *Reactions of spring barley cultivars to brown rust in a field nursery in 2002

| Cultivar [1-9 rating] | BBR factor | % Infection | Reaction type |
|---|---|---|---|
| Riviera [5] | | 30 | S |
| Simon | 3 | 28 | S |
| Pewter [4] | | 28 | S |
| Chalice [5] | | 28 | S |
| Sebastian | | 25 | S |
| Topic | | 25 | S |
| Quinn | 5 | 20 | S |
| Trumpf | 10 | 18 | S |
| Decanter [6] | | 13 | MS |
| Spire [6] | | 12 | MR |
| Adonis | | 10 | MR |
| Vortex | | 10 | MR |
| Cocktail [8] | | 10 | MS |
| Cellar [8] | | 10 | MR |
| Global [8] | | 8 | MR |
| Kirsty [8] | | 8 | MR |
| Optic [7] | | 5 | MS |
| Static [8] | | 5 | MR |
| Tavern | | 5 | MR |
| Colston | | 1 | R |
| County | | 0.1 | 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

## CROWN RUST OF OATS

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The number of samples received was at its highest for several years. Six races were identified which carried virulence to five of the ten seedling differential cvs. Race 251 was, as in recent years, dominant. Virulence to the winter oat cv. Millennium, which has a disease resistance rating of 9, was carried by 52% of the isolates and was geographically widespread. The newly recommended cv. Buffalo appears to carry the same resistance.

## INTRODUCTION

Thirty six samples of crown rust were received in 2002, the highest number for several years. They were sampled from winter oats (31), spring oats (4) and wild oats (1) (Table 1).

**Table 1** Source cvs of 2002 oat crown rust samples and their HGCA disease resistance rating [1= susceptible; 9= resistant] where known.

| Cv. | No. of samples | Cv. | No. of samples | Cv. | No. of samples |
|---|---|---|---|---|---|
| Winter oat | | | | Spring oat | |
| Gerald [6] | 5 | Ayr [6] | 2 | Firth [5] | 1 |
| Jalna [5] | 5 | Kingfisher [7] | 2 | Drummer [5] | 1 |
| Millennium[9] | 3 | Hendon [5] | 2 | Winston [6] | 1 |
| Icon | 3 | Buffalo [7] | 2 | Unknown | 1 |
| Lexicon | 2 | 93AW2/5/6/3 | 2 | Wild Oat | 1 |
| Grafton [6] | 2 | CPBT W01 | 1 | | |

The majority came from 2 trial sites at NIAB, Cambridge and Cockle Park, Northumberland. The remainder were sampled over a wide area of the UK (Table 2)

**Table 2** Geographic origins of oat crown rust samples in 2002

| Location | No. of isolates | Location | No. of isolates |
|---|---|---|---|
| Northumberland | 14 | Hampshire | 2 |
| Cambridge | 11 | Essex | 1 |
| Ceredigion | 4 | Mid Glamorgan | 1 |
| Devon | 2 | Grampians | 1 |

## SEEDLING TESTS WITH 2002 ISOLATES

### Methods

Isolates of *Puccinia coronata* were cultured from 21 samples and inoculated onto seedlings of the International Set of differential cvs as well as cv. Millennium which has a disease resistance rating of 9. Post-inoculation plants were incubated at approximately 15$^{o}$C in the glasshouse and after 14 days were assessed on reaction type on the standard 0-4 scale as resistant (0-2) or susceptible (3-4).

### Results

Some cvs expressed a mixed reaction to several of the isolates thus making classification as susceptible or resistant difficult. Isolates were, however, tentatively assigned race numbers from the International Register of Pathogenic Races of *Puccinia coronata*. Six races (Table 3) were identified carrying virulences in different combinations to five of the differential cvs. Virulence to four of these, cvs Appler, Bond, Anthony and Saia, is regularly identified in the pathotypes but virulence to cv. Landhafer was last identified in 1985. In 1985, this virulence was found in an isolate classified as race 256 and this was again so for the four isolates carrying the virulence in 2002.

**Table 3** Races identified from 2002 isolates

| Race | Susceptible differential cvs | No. of isolates |
|---|---|---|
| 251 | Appler, Bond, Saia | 10 |
| 256 | Anthony, Appler, Bond, Landhafer, Saia | 4 |
| 289 | Appler, Saia | 3 |
| 205 | Anthony, Appler, Bond, Saia | 2 |
| 236 | Anthony, Appler, Saia | 1 |
| 238 | Appler | 1 |

All races have been identified previously, with race 251 remaining dominant (Table 4).

Virulence to cv. Millennium was identified in 12 isolates. It was carried by races 251, 256, 236 and 289. The virulence was present in isolates cultured from samples received from Northumberland, Cambridge and Devon indicating that the virulence, first identified in a sample of cv. Millennium in 1999, is becoming widespread.

**Table 4** Frequency of races identified from 2002 isolates compared with previous 10 years.

| | Frequency | | | | | |
|---|---|---|---|---|---|---|
| Race | 1992 | 1994 | 1996 | 1998 | 2000 | 2002 |
| 205 | 0 | 0.08 | 0 | 0 | 0 | 0.10 |
| 236 | 0 | 0 | 0 | 0 | 0.05 | 0.05 |
| 238 | 0 | 0 | 0 | 0 | 0 | 0.05 |
| 241 | 0 | 0.04 | 0 | 0 | 0 | 0 |
| 251 | 1.0 | 0.52 | 0 | 0.87 | 0.75 | 0.48 |
| 256 | 0 | 0 | 0 | 0 | 0 | 0.18 |
| 272 | 0 | 0 | 0.25 | 0 | 0 | 0 |
| 275 | 0 | 0.20 | 0 | 0.13 | 0.05 | 0 |
| 289 | 0 | 0.16 | 0.75 | 0 | 0.10 | 0.14 |
| 265 | 0 | 0 | 0 | 0 | 0.05 | 0 |
| No. of isolates | 1 | 25 | 4 | 8 | 20 | 21 |

## SEEDLING TESTS WITH SPECIFIC ISOLATES OF CROWN RUST

### Methods

Seedlings of winter oat cvs currently on the HGCA Recommended List, outmoded cvs and potential new cvs were grown in a spore-proofed glasshouse to the second leaf stage. Each cv. was inoculated separately with each of the following isolates:

| Isolate | Race | Cv. of Origin | |
|---|---|---|---|
| CRS-02-09 | 251 | Icon | NIAB, Cambridge |
| CRS-02-24 | 236 | Icon | Cockle Park, Northumberland |
| CRS-02-25 | 289 | Hendon | Cockle Park, Northumberland |
| CRS-02-26 | 289 | Buffalo | Cockle Park, Northumberland |

Post-inoculation plants were placed in dew-simulation chambers in the dark at 15$^{o}$C for 24 hrs. They were then incubated in the glasshouse at approximately 15$^{o}$C for 14 days when they were assessed for reaction type and classified as resistant (R: 0-2) or susceptible (S: 3-4).

## Results

**Table 5** Reaction of winter oat cvs to specific isolates of crown rust

| Cv. [1-9 rating] | Isolate | | | |
|---|---|---|---|---|
| | CRS-02-24 (Race 236) | CRS-02-26 (Race 289) | CRS-02-25 (Race 289) | CRS-02-09 (Race 251) |
| Millennium [9] | S | S | MR | S |
| Kingfisher [7] | S | S | S | S |
| Buffalo [7] | S | S | MR | S |
| Ayr [6] | S | S | S | S |
| Dalguise [3] | S | S | S | S |
| Krypton | S | S | S | S |
| Lexicon | S | S | S | S |
| 95-96 ACn3 | S | S | MR | S |
| Viscount | S | S | MR | S |
| Hendon [5] | S | S | S | S |
| Expression | S | S | S | S |
| Grafton [6] | S | S | S | S |
| Jalna [5] | S | S | S | S |

[ ] HGCA disease resistance rating where 1 = susceptible; 9 = resistant
S = susceptible; MR = mixed resistant

All the cvs were susceptible to isolates CRS-02-24 (race 236), CRS-02-26 (race 289) and CRS-02-09 (race 251). However, four cvs gave a mixed resistant response to CRS-02-25 (race 289). They were cv. Millennium, the outmoded cv. Viscount which has previously shown a similar pattern of responses to a range of isolates as cv. Millennium, the newly recommended cv. Buffalo and the potential new cv. 95-96 A Cn3 (Mascani). It is likely these lines carry the same resistance, but this may be of little value as virulence to cv. Millennium appears to be becoming widespread.

## RHYNCHOSPORIUM OF BARLEY

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Frequencies of the virulence factors were similar to those of recent years, with BRV-5 and BRV-6 at low levels. Virulence to BRR-8 (cv. Digger), was not identified. Of the potential new cvs Novello appears to carry BRR-8 and the winter barley cv. Clara, BRR-5. BRR-2 was identified in several of the other 'new' winter barleys including cvs Antelope, Swallow, Aquarelle, Wigwam, Nocturne, Connoisseur and Colossus. In field nurseries a number of winter barleys were resistant but spring barleys on the HGCA Recommended List were susceptible. The potential new cv. Novello was resistant.

## INTRODUCTION

One hundred and sixteen samples of leaf blotch, which has been the most severe foliar disease of winter barley since 1998, were received. Of these, 87 were from winter barleys (Table 1) and 29 from spring barleys (Table 2). Geographically 51 samples were from Cambridge (mainly NIAB trial sites) and 14 from Cockle Park, Northumberland. The remainder were collected across 31 counties of England and Wales together with 1 from Aberdeen.

**Table 1** Source winter barley cultivars of 2002 leaf blotch samples

| Cv. | No. of samples | Cv. | No. of samples | Cv. | No. of samples |
|---|---|---|---|---|---|
| Regina | 13 | Antonia | 2 | Muscat | 1 |
| Sumo | 8 | Opal | 2 | Parasol | 1 |
| Pearl | 7 | Pastoral | 2 | Kestrel | 1 |
| Vertige | 5 | Saigon | 2 | Pedigree | 1 |
| Haka | 5 | Swallow | 1 | Fanfare | 1 |
| Scylla | 4 | Antelope | 1 | Whisper | 1 |
| Jewel | 4 | Clara | 1 | Antigua | 1 |
| Heligan | 3 | Cannock | 1 | Hanna | 1 |
| Diamond | 3 | Carat | 1 | Virginia | 1 |
| Siberia | 3 | Angela | 1 | Unknown | 7 |
| Pict | 2 | | | | |

**Table 2** Source spring barley cultivars of 2002 leaf blotch samples

| Cv. | No. of samples | Cv. | No. of samples | Cv. | No. of samples |
|---|---|---|---|---|---|
| Riviera | 3 | Prestige | 2 | Global | 1 |
| Topic | 3 | Vortex | 2 | Cocktail | 1 |
| Decanter | 3 | Optic | 1 | Spire | 1 |
| Troon | 2 | Chalice | 1 | Barke | 1 |
| Cellar | 2 | Kirsty | 1 | Unknown | 3 |
| Static | 2 | | | | |

## SEEDLING TESTS WITH YEAR 2002 ISOLATES

### Methods

Isolates cultured from 73 samples were inoculated onto seedlings of the standard set of differential cultivars carrying different, specific resistant genes (Table3). Also included in the tests was cv. Pewter which has generally shown high levels of resistance and is thought to carry BRR-8.

**Table 3** Differential test cultivars for *Rhynchosporium secalis*

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

### Results

Table 4 gives virulence frequencies from the 2002 isolates and examples from the previous ten years' surveys. In 2002, no isolates were virulent on cv. Digger (BRR-8). BRV-8 has remained at a low frequency since it was first identified in 1990. Recently only the outmoded cv. Pewter and the potential new cv. Novello have been identified as carrying BRR-8. BRV-5 and BRV-6 were also at low levels in the 2002 isolates, with one or both of the corresponding resistance factors carried only by cvs Leonie and Clara of the current and potential new winter and spring barleys.

Virulence to Astrix (BRR-2) has shown increased frequency over the last decade. This may be attributed to BRR-2 being deployed in some of the most popular winter barleys in the mid 1990s (e.g. cvs Intro and Halcyon) and in 1997 BRR-2 cvs occupied over

40% of the winter barley hectarage, although this has subsequently decreased to 20% in 2002 (figures based on NIAB certified seed data). Also in recent years, as in 2002, many more samples have been received from winter barley crops even though spring barleys tend to be more susceptible. The reason for this apparent bias is unclear but the resultant data may not give a true representation of the frequencies of the different virulences in the entire pathogen population.

**Table 4** Frequencies of individual virulences, 1992-2002

| | BRV- | | | | | | | | No. of |
|---|---|---|---|---|---|---|---|---|---|
| Year | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | isolates |
| 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 |

All the virulence combinations present in the 2002 isolates have been identified previously (Table 5).

**Table 5** Virulence factor combinations identified from 2002 isolates

| No. of | Differential cultivars in linear order | | | | | | | | Race |
|---|---|---|---|---|---|---|---|---|---|
| isolates | Digger | Pirate | Osiris | La Mesita | Igri | Athene | Astrix | Armelle | octal |
| 5 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 14 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 24 |
| 1 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 104 |
| 14 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 114 |
| 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 7 |
| 9 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 17 |
| 4 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 107 |
| 36 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 117 |
| 1 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 137 |
| 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 177 |

1 – susceptible; 0 = resistant

The most complex race, octal 177, combined virulence to all the differential cvs with the exception of cv. Digger (BRR-8). This combination (BRV-1,2,3,4,5,6,7) identified in

one isolate and cultured from cv. Regina, was the only one to carry BRV-6. Race octal 117 (BRV-1,2,3,4,7) was as in 2000 and 2001 the prevalent pathotype.

## GLASSHOUSE ADULT PLANT AND SEEDLING TEST 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. Winter cvs included those on the HGCA Recommended List, newly introduced cvs and members of the standard differential set. The majority of the current HGCA Recommended List spring barleys have previously been shown, in glasshouse and field tests, to be highly susceptible to leaf blotch. Therefore, only recently introduced cvs, those which have previously expressed resistance, and the differential cvs were included in 2002 tests. 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-00-19 | 3,5,6,7 (164) | cv. Pipkin, Tayside |
| RS-02-69 | 1,2,3,4,7 (117) | cv. Regina, Leicestershire |
| RS-00-20 | 3,4,7,8 (314) | cv. Livet, Tayside |

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

### Seedling tests

Seedlings of the cvs included in adult plant tests, together with some potential new winter and spring barleys, were grown to the second leaf stage. 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) or susceptible (S).

### Results

### Winter barleys (Table 6):

Cultivars are grouped within Table 6 on the basis of similarities in the patterns of their responses to the isolates. Grouping does not necessarily imply that cvs within a group carry a common resistance factor(s). The levels of disease seen on some cvs in glasshouse tests are generally greater than those seen on the same cvs in field tests.

**Group 1:** Those cvs tested as adult plants were susceptible, although there were differences in infection levels between isolates and cvs. As seedlings, cvs were susceptible to the 3 isolates except for cvs Pict, Sequel and Angela. They showed lower levels of disease to isolates RS-00-19 and RS-00-20 and were classified as intermediate (I). In year 2001 tests, cv. Sequel was susceptible to these isolates, but cv. Pict was resistant, suggesting that it carried BRR-2. However, its adult plant reaction in 2002 tests indicate that this is not so. Likewise, the seedling reaction of cv. Angela in two previous years' tests suggested that it carried BRR-2 but its adult plant response in 2002 and in 2000, when it was also infected but at lower levels, do not confirm this. Further tests are needed.

**Group 2:** Cultivars were susceptible as adult plants to isolate RS-02-69 (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 except for cv. Parasol which was susceptible to the 3 isolates.

**Group 3:** As expected, cv. Igri, which carries BRR-4 was resistant to RS-00-19 but susceptible to the other isolates which carry matching virulence.

**Group 4:** The seedling responses of cvs Leonie and Clara suggest that they carry BRR-5. Cultivars with this resistance are typically resistant as seedlings to pathotypes lacking the corresponding virulence, but show various levels of susceptibility as adult plants.

### Spring barleys (Table 7):

The differential cvs carrying known specific resistances were seedling susceptible only to those isolates previously identified as carrying the corresponding virulence factors. Cultivars Novello and Pewter responded similarly to cv. Digger (BRR-8) although resistance is less readily expressed by cv. Pewter to some non-BRV-8 pathotypes. The remainder of the spring barleys were highly susceptible at both growth stages.

## ADULT PLANT FIELD ISOLATION NURSERIES

### Methods

Winter and spring barley nurseries were grown at a site conducive to the development of leaf blotch during the 2001-2002 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 developed on the susceptible cvs from endemic inoculum.

### Results

### Winter barleys (Table 8):

Reasonable levels of leaf blotch built up on the susceptible cvs during the season. The most susceptible cvs, Vertige, Sumo, Haka and Carat, showed disease levels similar to those they had expressed in 2001 field tests. Several of the other cvs, however, were less heavily infected than in the previous year when some, including cv. Regina, had shown

increased susceptibility to an artificially introduced isolate, RS-00-22. This isolate had been cultured from a more heavily than expected crop of cv. Regina (32% of flag leaf infected). However, low levels of the disease (<10% of flag leaf area infected) were reported on crops from which samples of cv. Regina were submitted to the 2002 Survey and this fails to confirm any increased virulence.

### Spring barleys (Table 9):

Disease levels on the susceptible cvs were generally lower than in the previous two years. Cultivars differed in the level of disease they developed but all of those on the 2002 HGCA Recommended List of spring barleys were susceptible. Cultivars Colston with 5% infection showed relatively good levels of resistance, although in glasshouse tests it had been susceptible (Table 7). Cultivars Pewter and Novello, thought to carry BRR-8, were resistant as were the differential cvs carrying known specific resistances. Subsequent seedling tests of an isolate cultured from a leaf sample taken from the nursery identified virulence factors BRV-3 and BRV-4 were present in the endemic population.

## ACKNOWLEDGEMENTS

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## REFERENCE

Jones, E.R.L. Clifford, B.C. and Newton, A.C. (1996) *Rhynchosporium* of barley. *UK Cereal Pathogen Virulence Survey 1995 Annual Report*, pp. 55-62.

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

| Cultivar/isolate [1-9 rating] | Group | RS-00-19 BRV-3,5,6,7 (Race octal 164) | RS-02-69 BRV-1,2,3,4,7 (Race octal 117) | RS-00-20 BRV-3,4,7,8 (Race octal 314) |
|---|---|---|---|---|
| Antonia [8] | 1 | 70 (S) | 40 (S) | 35 (S) |
| Saigon | | 50 (S) | 55 (S) | 35 (S) |
| Pastoral [7] | | 50 (S) | 25 (S) | 23 (S) |
| Carat [7] | | 50 (S) | 25 (S) | 28 (S) |
| Pearl [8] | | 35 (S) | 20 (S) | 20 (S) |
| Pict [8] | | 60 (I) | 50 (S) | 33 (I) |
| Sequel [8] | | 33 (I) | 33 (S) | 20 (I) |
| Angela [8] | | 20 (I) | 35 (S) | 18 (I) |
| Tallica | | - (S) | - (S) | - (S) |
| NSL 98-6329C | | - (S) | - (S) | - (S) |
| Haka [5] | | - (S) | - (S) | - (S) |
| Scylla [6] | | - (S) | - (S) | - (S) |
| Sumo [5] | | - (S) | - (S) | - (S) |
| Eden | | - (S) | - (S) | - (S) |
| Camion | | - (S) | - (S) | - (S) |
| Pirate (BRR-7) | | - (S) | - (S) | - (S) |
| Siberia [7] | 2 | 0 (R) | 43 (S) | 0 (R) |
| Regina [7] | | 0 (R) | 38 (S) | 0 (R) |
| Antelope | | 0 (R) | 28 (S) | 0 (R) |
| Swallow | | 0 (R) | 30 (S) | 5 (R) |
| Kestrel [8] | | 0 (R) | 25 (S) | 0 (R) |
| Cannock [8] | | 0 (R) | 23 (S) | 0 (R) |
| Parasol | | 0 (S) | 30 (S) | 0 (S) |
| Aquarelle | | - (R) | - (S) | - (R) |
| Wigwam | | - (R) | - (S) | - (R) |
| Vanessa | | - (R) | - (S) | - (R) |
| Nocturne | | - (R) | - (S) | - (R) |
| Connoisseur | | - (R) | - (S) | - (R) |
| Colossus | | - (R) | - (S) | - (R) |
| Igri (BRR-4) | 3 | - (R) | - (S) | - (S) |
| Leonie [9] | 4 | 25 (S) | 10 (R) | 10 (R) |
| Clara | | 15 (S) | 3 (R) | 5 (R) |

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

| Cultivar/Isolate [1-9 rating] | RS-00-19 BRV-3,5,6,7 (Race octal 164) | RS-02-69 BRV-1,2,3,4,7 (Race octal 117) | RS-00-20 BRV-3,4,7,8 (Race octal 314) |
|---|---|---|---|
| Vortex | 80 (S) | 65 (S) | 80 (S) |
| Adonis | 80 (S) | 60 (S) | 50 (S) |
| Kirsty [5] | 80 (S) | 70 (S) | 80 (S) |
| Sebastian | 70 (S) | 60 (S) | 80 (S) |
| Cocktail [5] | 65 (S) | 60 (S) | 60 (S) |
| Topic | 70 (S) | 45 (S) | 80 (S) |
| Troon | 65 (S) | 50 (S) | 68 (S) |
| Global | 65 (S) | 55 (S) | 65 (S) |
| Colston | 65 (S) | 30 (S) | 55 (S) |
| Armelle BRR-1 | 0 (R) | 33 (S) | 2 (R) |
| La Mesita BRR-5 | 70 (S) | 45 (R) | 40 (R) |
| Osiris BRR-6 | 55 (S) | 2 (R) | 7 (R) |
| Digger BRR-8 | 3 (I) | 0 (R) | 80 (S) |
| Novello | 4 (I) | 0 (R) | 70 (S) |
| Pewter | 10 (I) | 10 (I) | 60 (S) |

*Adult plants assessed on percentage area of flag leaf infected
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** *Infection of winter barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2002

| Cultivar [1-9 rating] | BRR factor | % total leaf area infected |
|---|---|---|
| Vertige [5] | | 26 |
| Sumo [5] | | 20 |
| Haka [5] | | 20 |
| Carat [7] | | 20 |
| Saigon | | 18 |
| Igri | 4 | 14 |
| Siberia [7] | | 14 |
| Heligan [7] | | 12 |
| Astrix | 2 | 10 |
| Opal [8] | | 10 |
| Pastoral [7] | | 8 |
| Clara | | 8 |
| Antelope | | 8 |
| Regina [7] | | 7 |
| Kestrel [8] | | 7 |
| Vanessa [8] | | 6 |
| Pirate | 7 | 6 |
| Leonie [9] | | 6 |
| Swallow | | 5 |
| Scylla [6] | | 4 |
| Fanfare [8] | | 4 |
| Muscat [8] | | 4 |
| Jewel [8] | | 3 |
| Athene | 3 | 3 |
| Diamond | | 3 |
| Parasol [7] | | 2 |
| Pedigree | | 2 |
| Antonia [8] | | 2 |
| Pearl [8] | | 2 |
| Pict [8] | | 1 |
| Sequel [8] | | 1 |
| Angela [8] | | 1 |
| Cannock [8] | | 0.5 |

*Mean of 4 replicates, final assessment date

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

**Table 9** *Infection of spring barley cultivars by *Rhynchosporium secalis* in a field isolation nursery in 2002

| Cultivar [1-9 rating] | BRR factor | % total leaf area infected |
|---|---|---|
| Vortex | | 31 |
| Sebastian | | 31 |
| Kirsty [5] | | 30 |
| Cocktail [5] | | 29 |
| Global | | 28 |
| Cellar [5] | | 28 |
| Topic | | 27 |
| Optic [4] | | 27 |
| Spire [5] | | 24 |
| Adonis | | 24 |
| Chalice [5] | | 23 |
| Riviera [5] | | 22 |
| Decanter [5] | | 22 |
| Troon | | 20 |
| Static [5] | | 19 |
| Tavern | | 16 |
| County | | 13 |
| Colston | | 5 |
| La Mesita | 5 | 4 |
| Armelle | 1 | 1 |
| Pewter | (8?) | 0.7 |
| Digger | 8 | 0.4 |
| Novello | (8?) | 0.2 |
| Osiris | 6 | 0 |

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

## NET BLOTCH OF BARLEY

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Winter barley cvs displayed a range of quantitative responses to a mixed inoculum prepared from the 2002 samples, with cv. rankings generally confirming their HGCA Recommended List disease resistance ratings. Some recommended cvs expressed high levels of adult plant resistance. Of the potential new cvs, only cv. Pedigree was seedling resistant but, as in some other cvs, this resistance may not be effective at later growth stages.

## INTRODUCTION

Forty one samples of net blotch were received in 2002, the highest number since 1997. However, where recorded, infection levels on the sampled crops were generally low.

The samples were all from winter barleys (Table 1). Twenty were from Cambridge, mostly from NIAB trial sites, with the remainder being collected across 15 English counties from Cornwall to North Yorkshire.

**Table 1** Source cultivars of 2002 net blotch samples

| Cv. | No. of samples | Cv. | No. of samples | Cv. | No. of samples |
|---|---|---|---|---|---|
| Pearl | 10 | Parasol | 2 | Muscat | 1 |
| Siberia | 5 | Opal | 1 | Pict | 1 |
| Regina | 4 | Scylla | 1 | Sequel | 1 |
| Heligan | 3 | Carat | 1 | Antelope | 1 |
| Jewel | 3 | Diamond | 1 | Kestrel | 1 |
| Unknown | 3 | Angela | 1 | Pastoral | 1 |

## METHODS

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

### Adult plant tests

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

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

### Seedling tests

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

## RESULTS (Table 2)

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

As adult plants cvs expressed a range of quantitative responses with cv. rankings generally confirming their 1-9 disease resistance ratings. Cultivar Pearl was, as in previous years' tests, infected at relatively lower levels than would be expected from its disease rating of 5. Cultivars Leonie, Antelope and Saigon were highly resistant as was cv. Scylla. This cv. was, however, susceptible to a mixture of isolates in 2001 tests. As in previous years, the seedling resistances of cvs Angela and Sequel were effective. However, as adult plants, they were susceptible. Other cvs showing seedling resistance were cv. Pedigree and the highly resistant cv. Leonie.

The seedling responses of the differential cvs identified the pathotypes as carrying only 3 virulences, 4, 9 and 11 which have previously been identified at high frequencies in the UK pathogen population.

## REFERENCE

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

**Table 2** *Reactions of winter barley cultivars as adult plants and seedlings, to a mixture of net blotch isolates in glasshouse tests

| Cultivar [1-9 Rating] | Adult plant % infection | Seedling reaction | Cultivar | Differential code number | Seedling reaction |
|---|---|---|---|---|---|
| Regina [5] | 30 | S | Pedigree | | R |
| Parasol | 30 | S | Connoisseur | | S |
| Angela [4] | 25 | R | Eden | | S |
| Siberia [5] | 25 | S | Colossus | | S |
| Pict [6] | 25 | S | Camion | | S |
| Carat [7] | 20 | S | Tallica | | S |
| Kestrel [7] | 20 | S | NSL 98-6329C | | S |
| Pearl [5] | 15 | S | Aquarelle | | S |
| Swallow | 15 | S | Nocturne | | S |
| Clara | 15 | S | Wigwam | | S |
| Diamond [7] | 15 | S | Vanessa | | S |
| Sequel [7] | 15 | R | CI 5401 | 1 | R |
| Heligan [7] | 15 | S | CI 6311 | 2 | R |
| Sumo [8] | 15 | S | CI 9820 | 3 | R |
| Haka [8] | 12 | S | CI 739 | 4 | S |
| Pastoral [8] | 10 | S | CI 1243 | 5 | R |
| Jewel [7] | 6 | S | CI 4795 | 6 | R |
| Antonia [8] | 5 | S | CI 4502 | 7 | R |
| Cannock [9] | 5 | S | CI 4979 | 8 | R |
| Scylla [8] | 1 | S | Proctor | 9 | S |
| Antelope | 1 | S | CI 9214 | 10 | R |
| Leonie [9] | 1 | R | CI 9518 | 11 | S |
| Saigon | 1 | S | Tenn61-119 | 12 | R |
| | | | Code 65 | 13 | R |

* Adult plants assessed on % flag leaf area infected, 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)
[ ] Disease resistance rating: 1 = susceptible; 9 = resistant