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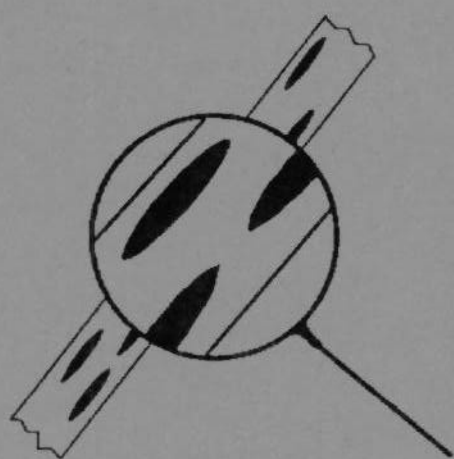
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1996 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

OBJECTIVES

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

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

METHODS

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

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

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

At each centre, virulence is measured by inoculating seedlings and/or adult plants with spores multiplied from the disease samples.

Seedling tests are usually carried out under controlled environment conditions. Adult plant tests are carried out in the field, in Polythene tunnels or in controlled environment rooms.

RESULTS

The United Kingdom Cereal Pathogen Virulence Survey Committee meets annually to discuss the scientific and agricultural significance of the results of virulence tests carried out during the previous year. The results are used to place wheat and barley cultivars in diversification groups on the basis of their specific resistances. The results of the virulence tests and the diversification schemes are published in the Annual Report.

The information provided by the Survey is used in several ways. Isolates possessing new virulences are used by the National Institute of Agricultural Botany to evaluate the resistance of cereal cultivars in official trials and by plant breeders to select lines with effective forms of resistance. Isolates are also supplied to Universities and Colleges for research projects and teaching purposes. Versions of the cultivar diversification schemes, modified to meet regional requirements, are published by the National Institute of Agricultural Botany and the Scottish Agricultural College.

The UKCPVS is funded by MAFF and HGCA, with a contribution from breeders through fees charged for National List testing.

EXPLANATION OF TERMS USED TO DESCRIBE RESISTANCE AND VIRULENCE

Specific resistance and specific virulence

Resistance is the ability of a host cultivar to defend itself against infection by a pathogen isolate. Conversely, virulence is the ability of a pathogen isolate to infect a host cultivar.

Some cultivars possess resistance that is more effective against some isolates than others and this is termed "specific resistance". Similarly, some isolates are more able to infect some cultivars than others and this is termed "specific virulence".

The terms "specific resistance factor" and "specific virulence factor" are used to describe unidentified genes in host and pathogen which interact with one another. Specific resistance factors are numbered R1, R2 ... Rn and specific virulences are numbered V1, V2 ... Vn. Each individual specific resistance factor is effective against all isolates except those possessing the corresponding virulence factor. Hence a cultivar possessing R4 has effective resistance against all isolates except those possessing V4. Cultivars lacking specific resistance are classified as RO and isolates lacking specific virulence are classified VO.

Specific resistances and virulences relating to particular cereal diseases are described by additional prefixes for crop (W = wheat, B = barley, O = oats) and disease (M = mildew, Y = yellow rust, B = brown rust, C = crown rust, R = Rhynchosporium), hence WYR 2 and BMV 5.

Terms describing resistance at different growth stages

Resistances may also be classified according to the growth stages at which they are effective:

- overall resistances
  are effective at all growth stages

- seedling resistances
  are effective at seedling growth stages but ineffective at adult plant growth stages

- adult plant resistances
  are effective at adult plant growth stages but ineffective at seedling growth stages

SUMMARY OF RESULTS FOR 1996

Mildew of wheat

Virulence factors *V2, 4b, 5, 6, 8* and *Ta2*, corresponding to commonly used resistance factors in current wheat cultivars, occurred at frequency levels between 90 and 100% in the mildew population. Virulence for *Pm3b* and *Pm17* was detected at levels similar to 1995, despite no obvious selection by host cultivars, although these resistance factors are being investigated by plant breeders. The pathotype spectrum was similar to 1995, with one pathotype consisting of the above virulence factors dominating the population at a frequency of 35%. This pathotype was able to infect all current winter wheat cultivars on the 1997 NIAB Recommended List, with the exception of Cadenza and Spark. 1996 fungicide resistance studies suggested that there has been some shift towards insensitivity to morpholine fungicides in wheat mildew isolates since 1994.

Yellow rust of wheat

Virulence for the resistance WYR 17, derived from Rendezvous and present in commercial cultivars such as Brigadier and Hussar, was confirmed on adult plants in tests of isolates collected in 1995. In 1996, the frequency of WYV 17 increased to 75%. A new virulence combination, WYV 17 with WYV 6, was detected for the first time. Seedling tests indicate that this new pathotype overcomes the resistance of a number of cultivars that are resistant to other pathotypes carrying WYV 17, including Equinox, Madrigal and Lynx.

Brown rust of wheat

Seedling tests identified Promessa and the Thatcher backcross line Lr1 as carrying a common resistance. Lines Lr 21, Lr 26 and Lr 28, included in tests for the first time, were resistant at 10°C and 25°C. Virulence for Chablis, Cadenza, Spark and Axona identified in controlled environment tests at 25°C in 1995 was not confirmed in the field, with the majority of the current NIAB Recommended varieties carrying effective resistance. An isolate which was virulent on Promessa in seedling tests failed to infect it in controlled environment tests. Hereward and Spark, previously thought to carry a common resistance, were differentiated by one isolate in these tests.

Mildew of barley

Virulence factors corresponding to commonly used resistances in current cultivars were again recorded at high levels. The mildew population remains complex and heterogeneous: numerous pathotypes carry at least seven virulence factors. *Mlo* resistance remains complete in all areas. The virulence combination *VLa,Vla13*, corresponding to the spring barley cultivar Tyne, increased in incidence in Northern Ireland.

Yellow rust of barley

No samples were received in 1996. Seedling tests confirmed the virulence factors in 12 isolates from 1974-1994 and also the resistance genes in recommended winter and spring cultivars. A wide range of resistance was demonstrated in adult plant field tests, but these showed that susceptible cultivars present a potential risk if widely grown.

Brown rust of barley

Virulence factor BBV3 was found at similar levels in the pathogen population to 1995 when it showed an increased frequency. This increase in BBV3 pathotypes may explain the higher than expected disease levels on some spring barley cultivars which appear to carry BBR3. The possible increase in virulence to some other spring barleys requires monitoring. Adult plant tests identified some winter barley cultivars as carrying effective resistance, with a number of spring barleys having adult plant resistance.

Rhynchosporium of barley

Seedling tests with 1994 and 1995 samples identified some isolates as carrying increased virulence to the previously resistant spring barley cultivar Digger. This was confirmed in 1996 glasshouse adult plant tests when Digger was highly susceptible. Livet also appears to carry this race-specific resistance. Several winter barley cultivars carry BRR2, whilst the adult plant resistance of Manitou remains effective. The majority of the spring barley cultivars were susceptible as seedlings and adult plants.

Net blotch of barley

Virulences were generally at a higher frequency to all the test cultivars than for several years. The virulences identified occurred in 50 varying combinations in the different isolates, with virulence combinations ranging from single virulence factors in some isolates to one isolate carrying virulence to all cultivars. The majority of the current NIAB Recommended winter barleys were susceptible in adult plant glasshouse tests, although Tokyo, Regina, Prelude, Pipkin and Hanna were classified as resistant. Several of the spring barleys were resistant.

Soilborne mosaic viruses of barley

178 infected samples were received in 1996: 46% contained barley yellow mosaic virus (BaYMV) and 67 % barley mild mosaic virus (BaMMV). Largest numbers of samples were from Puffin, Halcyon and Fighter. BaMMV predominated on Puffin and Halcyon, often producing very pronounced symptoms. One new outbreak of resistance-breaking BaYMV was reported. Virus (BaMMV) was reported in Lothian, Scotland for the first time.

Mildew of oats

The relatively complex race 5 (OMV1,2,3) was identified in 80% of the 1996 isolates, with the remainder combining these virulence factors with OMV4 (race 7).

Crown rust of oats

Seedling tests with the 1996 samples identified races 272 and 289. The spring oat cultivar Piper was resistant to these races.

MILDEW OF WHEAT

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Virulence frequencies were similar to, or slightly higher than, 1995 values. Virulence factors corresponding to the most common specific resistances in current wheat cultivars remained almost fixed in the mildew population. Virulence for *Pm3b* and *Pm17* was again detected, despite no obvious selection for the corresponding virulence factors. The pathotype spectrum continued to exhibit reduced heterogeneity; the predominant pathotype can infect all NIAB 1997 Recommended List cultivars except Cadenza and Spark. The proportion of isolates able to infect these cultivars increased in 1996.

INTRODUCTION

Inoculum survived the winter well, leading to early establishment of mildew in the spring. Mildew incidence and severity were moderate in the UK as a whole in 1996 but warm, dry conditions in summer led to higher than average levels in Eastern areas. Here, mildew became well established on most cultivars, necessitating considerable fungicide usage.

METHODS

A total of 315 samples of wheat mildew was received in 1996, mostly from trial plots. Between two and five single colony isolates were successfully cultured from 124 samples. The isolates were taken from infected leaves of the following cultivars:

Winter cultivars	No. of isolates		No. of isolates		No. of isolates
Cadenza	42	Dynamo	6	Hereward	2
Hunter	39	Caxton	4	Encore	2
Genesis	34	Chianti	4	Buster	2
Consort	33	Magellan	4	Brigadier	2
Equinox	12	Ritmo	4	Chaucer	2
Harrier	11	Vivant	4	Weston	2
Madrigal	10	Hussar	4	Elsoms 957	2
Charger	9	Mercia	4	Victo	2
Drake	9	Beaufort	4	Z74/2P	2
Abbot	8	Soissons	4	Riband	1
Reaper	7	Raleigh	3		
Shango	6	Spark	3		

Spring cultivars

Chablis	6	Palermo	4	Axona	2
Ebony	4	Shiraz	4		
Total	313				

The samples were collected from the following locations:

	No. of isolates		No. of isolates
NIAB, Cambridge	82	Wye, Kent	35
Spalding, Lincs.	50	Harper Adams, Salop	25
Bridgets, Hants.	46	Headley Hall, Yorks.	24
Cockle Park, Northumb.	40	Morley, Norfolk	11
Total	313		

66 samples failed to produce viable conidia, and a further 124 isolates taken were not tested. Isolates were inoculated onto detached leaf segments of differential cultivars and assessed for virulence on a 0-4 scale for infection type (Moseman *et al*, 1965). Differential cultivars used to test the isolates for virulence factors are shown in Table 1.

Table 1. Differential cultivars used to determine virulence factors in isolates of wheat mildew in 1996.

	Resistance factors		
Differential cultivar	European code	UK WMR group	Resistance genes
Cerco	none	0	none
Galahad	Pm2	2	*Pm2*
Armada	Pm4b	4	*Pm4b*
Flanders	Pm5	5	*Pm5*
Brimstone	Pm2, Pm6	2,6	*Pm2, Pm6*
Clement	Pm8	7	*Pm8*
Amigo	Pm17	10	*Pm17*
Maris Dove	Mld	9	*Mld*
Brock	Pm2, MlTa2	2,'Talent'	*Pm2,* unknown
Mercia	Pm5, MlTa2	5,'Talent'	*Pm5,* unknown
Tonic	Pm3d, MlTo	p	*Pm3d,* unknown
Broom	Pm3d	q	*Pm3d*
Sicco	Pm5, MlSi2	5,r	*Pm5,* unknown
Wembley	MlSo	'Sona'	unknown
Axona	MlAx	'Axona'	unknown
Cadenza	MlAx (Mld, Pm3d?)	'Axona' (+9,q?)	unknown

RESULTS

Virulence frequencies

The frequencies of specific virulence factors recorded in 1996, and in the five previous years, are given in Table 2. Virulence factors *2*, *4b*, *5*, *6*, *8* and *Ta2*, corresponding to common resistance factors used in current wheat cultivars, remained at high levels in the population. Most had increased slightly in frequency in 1996, compared with 1995 (Slater & Clarkson, 1996). Levels of *Vd*, *V3d To*, *V3d*, *V5 Si2* and *VAx* had also markedly increased, although this may partly reflect the higher numbers of isolates from Cadenza tested in 1996. *V3b* and *V17* frequencies were similar to those of 1995, confirming their presence in the mildew population despite a lack of obvious selection for them by current cultivars. Renewed interest in using the corresponding resistance factors *Pm3b* and *Pm17* in new cultivars must therefore be questionable.

Table 2. Frequency of wheat mildew virulence factors in isolates from infected leaves collected in 1991 - 1996.

	Frequency of virulence factors (%)					
Virulence genes	1991	1992	1993	1994	1995	1996
2	100	99	98	99	99	100
3b	-	-	-	-	4	3
4b	69	73	79	84	88	93
5	92	90	95	92	92	93
6	80	76	78	80	89	96
8	80	86	93	93	95	96
17	-	-	-	-	10	15
d	-	27	15	20	19	33
2,Ta2	54	60	80	82	85	92
3d,To	9	24	18	24	18	29
3d	-	31	20	27	21	32
5,Si2	38	32	39	26	22	32
So	-	23	22	21	10	15
Ax	10	17	10	14	11	24
Number of isolates tested	300	194	356	347	265	313

Table 3 shows the frequency of the most common pathotypes of wheat mildew recorded in 1996 and previous years. The total number of pathotypes found was similar to that in 1995, maintaining the trend towards reduced heterogeneity in the population (Slater & Clarkson, 1996). This is in direct contrast with the barley mildew situation, in which low frequencies of a large number of pathotypes are the norm at present (Slater & Clarkson, 1997). The pathotype *2,4b,5,6,8,Ta2* still predominates, accounting for 35% of the pathotype population. This corresponds well with the rather limited number of common specific resistance genes in current wheat cultivars. There was an apparent increase in frequency of pathotype *2,4b,5,6,8,d,Ta2,3d, To,Si2,So,Ax* in 1996: again, this partly reflects the large number of isolates from Cadenza tested.

Table 3. Frequencies of the most commonly identified pathotypes in 1992 - 1996 as defined by the differential cultivars listed in Table 1.

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

* All pathotypes also carry V2

In Table 4, the proportion of the wheat mildew population screened which can potentially infect winter wheat cultivars on the NIAB Recommended List is indicated. The predominant pathotype is able to attack all cultivars except Cadenza and Spark. The proportion of isolates infecting these two cultivars was higher in 1996 compared with 1995; however more isolates from these cultivars were tested in 1996. 53% of isolates were able to infect Soissons: this cultivar was added to the differential set for the first time but its resistance factors remain obscure.

Table 4. The proportion of mildew isolates tested in 1996 able to infect winter wheat cultivars in Recommended List trials. (NIAB disease rating in brackets).

Cultivar	Proportion (%)	Cultivar	Proportion (%)
Brigadier (6)	87	Dynamo (7)	96
Hussar (7)	87	Encore (7)	96
Hunter (7)	96	Cadenza (7)	24
Riband (7)	90	Caxton (6)	100
Hereward (6)	100	Reaper (7)	96
Spark (7)	29	Soissons (8)	53
Mercia (5)	87	Equinox (6)	91
Rialto (7)	100	Charger (8)	100
Buster (5)	96	Abbot (7)	96
Beaufort (8)	91	Madrigal (6)	91
Consort (6)	90	Harrier (7)	87

Resistance Factors in New Cultivars

The specific resistance factors identified in wheat cultivars are shown in Table 5. No new resistance factors or combinations were found in 1996 tests. Reaper is now known to carry *Pm6*. The resistance factors thought to be carried by Cadenza need confirmation and the Soissons situation is still uncertain.

Table 5. Specific mildew resistance factors of winter wheat cultivars.

None	**Pm8**	**Pm2,Pm4b,Pm6**	**Pm4b,Pm6,Pm8(Pm2?)**
Genesis	Hunter	Riband	Brigadier
Hereward	Encore	Consort	Hussar
Rialto	Raleigh	Chianti	Harrier
Caxton	Drake	Magellan	
Charger		Malacca	**Pm5,MlTa2**
Fresco	**Pm2,Pm4b**		Mercia
Avital	Shango	**Pm2,Pm4b,Pm8**	
		Crofter	**Pm3d,MlTo**
Pm4b	**Pm2, Pm6**		Spark
Flame	Buster	**Pm6,Pm8**	
Impala	Dynamo	Beaufort	**MlAx(Mld,Pm3d?)**
	Abbot	Equinox	Cadenza
Pm6	Ritmo	Madrigal	
Reaper	Vivant		**Unknown**
			Soissons

Fungicide Sensitivity Tests

No random sample of isolates was taken from the 1996 survey, but 133 isolates were tested for fenpropimorph resistance in another study reported elsewhere (Bayles *et al*, 1997). Here, mildew samples from four cultivars in fungicide-treated and untreated trials at three sites (Cambridge, Kent, Northumberland) were compared. The results for the four cultivars are shown in Table 6; the Adjusted Resistance Factor is the ED_{50}/ED_{50} of the sensitive controls, adjusted for batch-to-batch variation.

The results cannot be directly compared with those of 1995, although comparison with the same insensitive control isolate used in 1994 indicated that 32% of isolates were less sensitive in 1996. Thus, there is an indication of some shift towards insensitivity to morpholine fungicides.

The tests showed that there were no significant differences in the sensitivity to fenpropimorph of isolates from the four cultivars. Also, isolates from untreated trials were, on average, unexpectedly less sensitive than those from treated trials. This was possibly due to a more heterogeneous mildew population, including strains from 1996 and 1995 treated crops, being present on the untreated trials.

Table 6. Sensitivity of wheat mildew isolates to fenpropimorph, 1996

Cultivar	No. of isolates	Mean ED_{50}	Mean ARF*
Cadenza	35	31.9	5.6
Consort	31	27.2	5.4
Genesis	32	28.5	5.8
Hunter	35	36.8	5.4
Sensitive controls	2	7.4	-
Insensitive controls	1	38.6	-

* = Adjusted Resistance Factor

CONCLUSIONS

Virulence factors corresponding to the most common host resistance factors remain almost fixed in the mildew population. Most showed an increase in frequency in 1996, although this was partly due to bias in sampling. Virulence for *Pm3b* and *Pm17* was detected at similar levels to 1995 (Slater & Clarkson, 1996), despite a lack of obvious selection by host cultivars. Thus, possible exploitation of these resistance genes in new cultivars must be questionable. The pathotype spectrum was similar to 1995, with pathotype *2,4b,5,6,8,Ta2* predominating, and continued to show reduced heterogeneity. This pathotype can infect all NIAB 1997

Recommended List cultivars except Cadenza and Spark. The proportion of isolates capable of attacking the latter cultivars increased in 1996.
No new resistance factors or combinations were detected. Reaper was found to carry *Pm6* but the specific resistances carried by Cadenza require confirmation; the situation with Soissons remains unclear. Reliance on a small number of largely ineffective specific resistance genes in wheat cultivars is of concern. Fortunately, good partial resistance is present in some cultivars, but note should be taken of new sources of specific resistance genes, eg *Pm22* (Peusha *et al*, 1996) and *mlre* (Robe & Doussinault, 1995).

Fungicide resistance work in 1996 indicated a shift towards insensitivity of wheat mildew isolates to fenpropimorph, compared with 1994 data.

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YELLOW RUST OF WHEAT

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Virulence for WYR 17 at the adult plant stage was confirmed in polythene tunnel tests of isolates collected in 1995. The frequency of this virulence reached 75% in seedling tests of 1996 isolates. A new virulence combination, WYV 17 with WYV 6, was detected. Seedling tests indicate that this new pathotype overcomes the resistance of a number of cultivars that are resistant to other pathotypes carrying WYV 17.

SEEDLING TESTS OF 1996 ISOLATES

Isolates of *Puccinia striiformis* were tested for virulence on seedlings of the differential cultivars listed in Table 1, using the methods described by Priestley, Bayles and Thomas, 1984. The incidence of yellow rust in 1996 was extremely low and only 32 isolates from natural infections were tested. All isolates were derived from samples collected in the traditional high risk areas of Cambridgeshire, Lincolnshire and Norfolk. 20 isolates were from varieties known to carry the WYR 17 resistance. An additional five isolates from inoculated plots were tested, but results of these were excluded from the estimation of virulence frequencies. One of these, 96/502, from an inoculated plot of Madrigal, possessed a new virulence combination of WYV 17 with WYV 6 (WYV 1,2,3,6,9,17) and was virulent on Magellan, Equinox, Lynx and Raleigh as well as Madrigal itself. The significance of the WYV 6 ,17 combination cannot be fully assessed until 96/502 has been tested on adult plants of a wide range of cultivars with Yr17 in their parentage. However, it seems likely that many which were resistant to the original WYV 17 pathotypes will prove susceptible.

Seedling virulence frequencies, based on isolates from natural infections are given in Table 2. The frequencies of WYV 1, WYV 2, WYV 3 and WYV 9 remained at, or close to, 100%. The frequency of WYV 4, at 59%, was similar to that in 1995, having declined from a peak in the late 1980s / early 1990s. The frequency of WYV 6 fell to 16%, its lowest level since 1977. WYV 17 (virulence for Rendezvous, Brigadier and Hussar) reached 75-80%.

Table 1. Differential cultivars used in seedling virulence tests in 1996

Differential Cultivar	WYR Factor	Gene	Cultivar Code
Main set			
Chinese 166	WYR 1	Yr1	
Heines VII	WYR 2	Yr2	
Cappelle Desprez	WYR 3	Yr3a + 4a	
Hybrid 46	WYR 4	Yr3b + 4b	
Heines Kolben	WYR 6	Yr6	
Tommy	WYR 7	Yr7	
Compair	WYR 8	Yr8	
Kavkaz x 4 Federation	WYR 9	Yr9	
Additional set			
Carstens V	WYR CV		CV
Hereward	WYR CV+		He
Rendezvous	WYR 17	Yr17	Re
Brigadier	WYR 9,17	Yr9+Yr17	Br
Hussar	WYR 9,17	Yr9+Yr17	Hu
Madrigal	WYR 6,9,17	Yr6+Yr9+Yr17	Ma
Cadenza	WYR Rx (Tonic)		Ca
Parade	WYR Rx		Pa

Table 2 Virulence factor frequency % (from natural infection)

Year	'82	'83	'84	'85'	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96
WYV 1	63	85	75	76	78	87	68	62	85	91	88	89	65	90	97
WYV 2	100	100	100	100	100	100	100	100	100	100	100	98	100	99	97
WYV 3	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
WYV 4	37	20	31	45	70	47	78	97	91	86	86	89	86	67	59
WYV 6	29	26	64	90	96	89	72	57	69	64	88	68	41	35	16
WYV 7	5	0	3	3	22	8	6	2	9	19	7	8	4	0	3
WYV 8	2	0	0	*	*	*	*	*	*	0	0	0	0	0	0
WYV 9	2	23	31	3	4	5	66	99	94	88	76	84	94	95	97
Virulence for cultivars in additional set															
Carstens V													75	55	9
Hereward											36	47	35	10	6
Rendezvous													57	~~57~~ 70	84
Brigadier											40	~~40~~ 35	~~35~~ 10	~~10~~ 40	78
Hussar										12	~~29~~ 1/	32	6	40	75
Cadenza											0	2	0	0	0
Parade											3	0	0	0	0
Madrigal															0
No. of isolates	41	63	36	29	23	52	71	156	67	42	77	63	49	83	32

ADULT PLANT TESTS OF 1995 ISOLATES

18 isolates from the 1995 survey (Table 3) and a mixture of the remaining 1995 isolates were tested for virulence on adult plants of 30 cultivars in Polythene tunnels and on seedlings of the same cultivars. The isolates were chosen on the basis of their seedling virulence characteristics and source cultivar.

Table 3. Isolates of *Puccinia striiformis* used in adult plant tests

Isolate code	Source		WYV Factors	Additional virulence*
	Cultivar	Location		
95/46	Brigadier	Cambs	1,2,3,9	Br, Hu,Re
95/77	Brigadier	Norfolk	1,2,3,4,9	Br, Hu, Re
95/12	Brigadier	Lincs	1,2,3,4,9	Br, Hu
95/44	Hussar	Cambs	1,2,3,9	Br, Hu, Re
95/68	Mohawk	Cambs	1,2,3,9	He, Br, Hu, Re
95/93	Brigadier	Lincs	1,2,3,4,9	Br, Hu, Re
95/15	Brigadier	Cambs	1,2,3,9	Br, Hu
95/66	Acclaim	Cambs	1,2,3,9	Br, Hu, Re
95/23	Beaufort	Cambs	1,2,3,9	Br, Hu, Re
95/502	Hussar	Poly tunnel test	1,2,3,9	Br, Hu, Re
95/17	Reaper	Cambs	1,2,3,9	CV, Br, Hu, Re
95/80	Raleigh	Norfolk	1,2,3,4,6,9	-
95/88	Encore	Cambs	1,2,3,4,6,9	He
95/512	Magellan	Poly tunnel test	1,2,3,4,6,9	-
95/21	Unknown	Norfolk	1,2,3,4,9	-
Mix		- mixture of remaining 1995 isolates-		
95/55	Flame	Norfolk	1,2,3,4,9	Re
95/50	Spark	Cambs	1,2,3,4,6,9	CV, He, Re
95/91	Charger	Cambs	2,3,4,6	CV, He Re

* cultivar codes as in Table 1

Adult plant polythene tunnel test results are given in Table 4.

The isolates fell into two groups. The first group, comprising 11 isolates from known or suspected WYR 17 cultivars, were virulent on the nine WYR 17 cultivars listed from Brigadier to Abbot and on the WYR 9 cultivar Slejpner, but avirulent on Haven (WYR 6,9). Some of these isolates also possessed virulence for the adult plant resistance WYR 13, as demonstrated by infection levels on Riband. The second group comprised eight isolates which were avirulent on WYR 17 cultivars. Seven of these isolates were virulent on Haven (WYR 6,9). Two isolates which had appeared to possess virulence for Hereward at the seedling stage (95/50 and 95/91) gave only very low levels of infection on adult plants of the cultivar.

The nine WYR 17 cultivars at the top of the table appeared to vary widely in background resistance, ranging from Brigadier at the susceptible end of the scale to Abbot at the more resistant end. Levels of infection on Brigadier were, on average, higher than on the highly susceptible WYR 9 cultivar Slejpner, which was associated with widespread epidemics in the late 1980's. It is possible however that, despite possessing WYV 9, the 1995 isolates may be less well adapted to Slejpner than those collected in earlier years when the cultivar was being widely grown.

The next five cultivars, also believed to have Yr17 in their parentage, were resistant to all isolates in polythene tunnels, but have since been shown to be susceptible to isolate 96/502 (WYV 1,2,3,6,9,17) in seedling tests. It is concluded that they carry the resistance WYR 17 combined with WYR 6. It appears likely from their parentage that most WYR 17 and WYR 6,17 cultivars also carry WYR 9. However, since all WYV 17 isolates identified to date also possess WYV 9, it has not been possible to confirm this.

The overall resistances of Cadenza, Buster and Consort and the adult plant resistances of Charger, Hunter, Encore, Apostle, Flame and Dynamo remained effective.

REFERENCE

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Table 4. **Adult plant tests 1996. Mean per cent leaf area infection (mean of 4 assessments)**

Cultivar	Isolate / WYR	95/46	95/77	95/12	95/44	95/68	95/93	95/15	95/66	95/23	95/502	95/17	95/80	95/88	95/512	95/21	MIX	95/55	95/50	95/91
		Virulence in seedling tests given in Table 3																		
Brigadier	9,17	47	36	27	24	24	23	19	19	18	15	13	2	Tr	Tr	0	Tr	Tr	4	3
Chianti	9,17	23	20	8	25	15	13	11	18	16	13	15	Tr	Tr	0	Tr	0	0	Tr	Tr
Harrier	9,17	14	23	9	19	16	11	11	18	11	12	9	Tr	0	0	0	0	0	2	5
Reaper	9,17	14	18	14	18	16	10	13	17	15	16	14	Tr	0	Tr	0	Tr	0	5	1
Beaufort	9,17	13	20	11	15	12	7	10	19	12	12	13	0	0	0	Tr	0	0	1	3
Hussar	9,17	10	18	13	17	7	8	4	9	6	4	6	Tr	0	0	0	0	0	1	3
Rendezvous	9,17	9	7	5	10	5	2	3	7	4	2	1	0	0	0	0	0	0	0	2
Drake	9,17	5	11	6	7	6	5	5	10	6	8	3	Tr	Tr	0	0	0	0	Tr	1
Abbot	17	4	4	Tr	3	1	Tr	1	3	1	2	Tr	0	0	0	0	0	0	0	0
Magellan	6,9,17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Equinox	6,9,17	0	Tr	1	0	Tr	Tr	0	Tr	0	0	Tr	0	0	0	0	0	0	0	0
Madrigal	6,9,17	Tr	0	0	0	0	0	0	Tr	0	0	0	0	0	0	0	0	0	0	0
Lynx	6,9,17	0	0	0	0	0	0	0	Tr	Tr	0	0	0	0	0	0	0	0	0	Tr
Raleigh	6,9,17	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Slejpner	9	10	21	7	26	13	7	7	25	9	9	10	19	11	4	6	2	5	9	2
Haven	6,9	0	Tr	0	0	Tr	Tr	Tr	0	0	Tr	0	14	12	10	9	7	5	11	0
Caxton	6	0	0	Tr	0	0	0	Tr	0	Tr	0	Tr	1	1	3	Tr	Tr	0	4	Tr
Hereward	CV+ Yr32	0	Tr	0	0	0	0	0	0	0	0	0	0	0	0	0	Tr	Tr	1	1
Spark	CV+	0	0	0	0	0	0	0	0	0	Tr	0	0	0	0	0	0	0	1	1
Riband	13	5	9	2	3	2	1	1	3	3	2	4	4	4	0	Tr	0	Tr	1	Tr
Crofter	?13	7	6	4	4	5	2	4	3	4	2	1	2	2	1	Tr	1	1	1	1
Charger	?6+APR	0	Tr	0	0	0	0	0	0	0	Tr	0	0	0	0	0	0	0	Tr	Tr
Hunter	6,9+APR	0	0	0	0	0	0	0	Tr	0	0	0	Tr	Tr	Tr	Tr	0	Tr	Tr	0
Encore	?6,9+APR	0	0	0	Tr	0	0	0	0	0	0	0	Tr	Tr	Tr	Tr	Tr	Tr	1	0
Apostle	2,6+APR	0	0	0	0	0	0	0	0	0	0	0	0	Tr	0	0	0	0	0	0
Flame	Rx+APR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Dynamo	Rx+APR	Tr	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cadenza	R Tonic	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	Tr	0
Buster	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Consort	R	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	Tr

Infection on the universally susceptible spreader variety Vuka was uniform across all tunnels, at around 25%.

BROWN RUST OF WHEAT

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The low incidence of wheat brown rust in 1996 was reflected in only one sample being received. Seedling tests with this isolate together with two received from the Czech Republic differentiated the resistances of some of the cultivars. Cultivars Caxton and Chablis were resistant in field nurseries to isolates thought to carry virulence to them. The majority of the current NIAB Recommended varieties were resistant in field nurseries and controlled environment tests to the isolates against which they were tested.

GLASSHOUSE SEEDLING TESTS WITH 1996 ISOLATES

Only one sample of wheat brown rust was received, this being sampled during the early winter of 1995 from cv. Caxton. An isolate of *Puccinia recondita* cultured from this sample was tested on a set of differential cultivars which comprised the standard WBR cultivars, cv. Thatcher backcross lines carrying different Lr resistance factors, and other spring and winter wheat cultivars from the NIAB Recommended List (Table 1). The Thatcher backcross lines Lr2b, Lr2c, Lr11, Lr14a, Lr17, Lr20, Lr21, Lr23, Lr26 and Lr28 were added to the lines included in previous years following discussions amongst members of COST Action 817 WG1, Sub-group "Wheat and Barley Leaf Rust" to establish a standard common set of differential cultivars.

Table 1. Differential cultivars

Standard differential cultivars (WBR-factor)	Thatcher Lr lines		Spring and winter cultivars	
Clement (1)	Lr 1	Lr 15	Fury	Harrier
Fundin (2)	Lr 2a	Lr 17	Shiraz	Charger
Norman (2)	Lr 2b	Lr 19	Chablis	Equinox
Hobbit (2)	Lr 2c	Lr 20	Ebony	Abbot
Sappo (3)	Lr 3	Lr 21	Palermo	Madrigal
Maris Halberd (4)	Lr 3bg	Lr 23	Avans	Maverick
Gamin (6)	Lr 3ka	Lr 24	Promessa	Cantata
Sterna (7)	Lr 9	Lr 26	Savannah	Crofter
Sabre (7)	Lr 11	Lr 28	Brigadier	Blaze
Armada (0)	Lr 14a		Hussar	

Also tested on the differential cultivars were two isolates received from Dr Pavel Bartoš, Czech Republic.

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

Results

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

Isolate	Virulence combination
WBRS-96-1 (ex Caxton)	WBV-3,4,6
WBR-1947-77 Sa Ba	WBV-6
WBR-347-77	WBV-6,7

Although the isolates received from the Czech Republic were identified as only carrying either one or two virulence factors, they had infected cvs Promessa and Avans in seedling tests carried out at the Research Institute for Crop Production, Prague. In those tests cvs Promessa and Avans responded similarly to a range of isolates suggesting they may carry a common resistance. They have been resistant to the majority of isolates against which they have been tested in the UK although cv. Avans is less resistant at 25°C to some isolates. In 1996 seedling tests cv. Avans was susceptible (mixed reaction) to isolates WBR-347-77 and WBR-1947-77 Sa Ba but resistant at 10°C to isolate WBRS-96-1. Cultivar Promessa was susceptible only to isolate WBR-347-77 indicating that it carries different or additional resistance(s) to cv. Avans.

Cultivars Harrier, Equinox, Drake, Madrigal, Blaze, Savannah, Hussar, Brigadier and Crofter were resistant at both temperature regimes to the three isolates, while cvs Maverick, Cantata, and Caxton were susceptible.

The remaining cultivars carry temperature-sensitive resistances (Table 2).

Cultivar Chablis, as in previous years' tests, gave a similar pattern of responses to the isolates as cvs Sterna (WBR-7) and Sabre (WBR-7). The temperature-sensitive resistance of these cultivars has been effective at 25°C to the majority of isolates tested. Cultivars Abbot and Charger also expressed a more resistant reaction to the isolates at the higher temperature regime. Cultivar Shiraz, which has previously been susceptible only at 25°C to isolates carrying WBV-7, was again susceptible at that temperature to such an isolate (WBR-347-77). Resistance conferred by cv. Ebony was more readily expressed at 10°C.

The reactions of the Thatcher-Lr backcross lines, which are known to carry specific Lr genes, to the isolates are given in Table 3. The temperature-sensitive resistance of Lr1 has been effective at 25°C to the majority of isolates tested in recent years. Isolates which have overcome this resistance have also shown increased virulence to cv. Promessa (Jones and Clifford, 1995). In

1996 seedling tests Lr1 was susceptible to isolate WBR-374-77 as was cv. Promessa suggesting that they carry a common resistance. These two cultivars were resistant to isolate WBR-1947-77 Sa Ba although cv. Promessa was susceptible in tests carried out in Prague. Also susceptible to isolate WBR-347-77 only were lines from the Lr2 and Lr3 groups, Lr11 and Lr15.

Resistance conferred by Lr20, Lr17 and Lr23 was effective at either 10°C (Lr20) or 25°C (Lr17 and Lr23). The line Lr14a was susceptible to all the isolates whereas resistance conferred by Lr9, Lr19, Lr21, Lr24, Lr26 and Lr28 was effective.

Table 2. *Reactions of wheat cultivars expressing a temperature-sensitive response in 1996 seedling tests.

Cultivar / Isolate	WBR-347-77 (WBV-6,7)		WBRS-1947-77 Sa Ba (WBV-6)		WBRS-96-1 (WBV-3,4,6)	
	10°C	25°C	10°C	25°C	10°C	25°C
Shiraz	R	S	MR	MR	MR	MR
Chablis	S	MS	S	MR	S	MR
Abbot	S	MR	S	MR	S	MS
Charger	S	MR	S	MS	S	MS
Ebony	MR	MS	MR	MS	MR	MR

*Reactions classified on the standard 0-4 scale as resistant (R = 0-2) or susceptible (S = 3-4)

R = resistant S = susceptible

MR = mixed resistant MS = mixed susceptible

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

Isolate (WBV-)	Post inoculation incubation temperature	Thatcher Line (Lr gene)									
			Lr1	Lr2a	Lr2b	Lr2c	Lr3	Lr3bg	Lr3ka	Lr9	Lr11
WBR-347-77	10°C		S	MS	MS	S	S	S	S	R	MS
(6,7)	25°C		S	MS	MS	MS	MS	MS	MS	R	MS
WBR-1947-77 Sa Ba	10°C		MR	MR	R	MR	MS	MS	MS	R	MR
(6)	25°C		MR	MR	R	MR	R	R	R	R	MS
WBRS-96-1	10°C		S	R	R	R	MS	MS	S	R	MR
(3,4,6)	25°C		R	-	R	MR	R	R	R	R	MS
		Lr14a	Lr15	Lr17	Lr19	Lr20	Lr21	Lr23	Lr24	Lr26	Lr28
WBR-347-77	10°C	S	MS	S	R	MR	MR	S	MR	MR	R
(6)	25°C	S	MS	MR	R	MS	MR	MR	R	MR	R
WBR-1947-77 Sa Ba	10°C	S	R	S	R	MR	R	S	MR	MR	R
(6)	25°C	S	MR	MR	R	MS	MR	MR	R	MR	R
WBRS-96-1	10°C	S	R	S	R	MR	MR	S	MR	R	MR
(3,4,6)	25°C	MS	MR	R	R	MS	R	MR	R	R	R

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

R = resistant S = susceptible

MR = mixed resistant MS = mixed susceptible

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Winter and spring wheat cultivars were sown in each of three nurseries in the 1995-1996 season using standard procedures (Clifford, Jones and Priestley, 1978). The nurseries were each inoculated with one of the following isolates of *P. recondita*.

Isolate	Origin
WBRS-95-19	cv. Chablis
WBRS-96-1	cv. Caxton
WBRS-94-50	cv. Flame

Results

These are summarised in Table 4. As in the previous season disease was slow to build up within the nurseries so it was late in the season before the susceptible cultivars showed reasonable levels of infection. The majority of the cultivars were highly resistant to the isolates. Because the resistances carried by the majority of the current NIAB recommended varieties remain effective against isolates cultured from samples received by the survey, it is difficult to identify different specific resistances that these cultivars may carry. Many of the resistant cultivars are thus grouped together (Group 13) within Table 4 in the absence of isolates able to differentiate cultivar resistances. Other cultivars have been classified into groups using data from previous years' adult plant and seedling tests and the basis for the grouping of many of the cultivars has been discussed previously (Jones and Clifford, 1995, 1996). It should not be interpreted that cultivars within a group carry a common resistance factor(s). Within Group 1 isolate WBRS-94-50 failed to infect cv. Clement (WBR-1) although it had done so in 1995 field tests and previous seedling tests. Isolate WBRS-95-19 which was also identified as carrying WBV-1 in seedling tests induced low levels of infection (4%). Cultivar Sappo (WBR-3) was susceptible to the isolates although only isolate WBRS-96-1 carried virulence to it in seedling tests. The other two isolates only infected cv. Sappo at 25°C in seedling tests. Cultivar Halberd (WBR-4) showed a similar pattern of responses to the isolates to cv. Sappo in seedling tests but was resistant in the field nurseries.

Isolate WBRS-95-19 was cultured from heavily infected flag leaves of cv. Chablis. In 1995 controlled environment adult plant tests it failed to induce the high levels of infection on cv. Chablis that would be expected from the disease levels shown on the original sample (Jones and Clifford, 1996). In 1996 field tests only traces of rust were seen on cv. Chablis inoculated with isolate BRS-95-19. Cultivars Cadenza, Spark and Axona were susceptible at 25°C to this isolate in the same controlled environment tests, the resistance of the latter having previously been effective at low and high temperatures against all other isolates. In 1996 field tests they were all resistant to isolate WBRS-95-19.

Group 6, 9 and 11 cultivars were susceptible to isolate WBRS-94-50 in 1995 field tests as were cvs Imp and Minx (Group 12) but were resistant to the same isolate in 1996 field tests, suggesting that the nursery had become infected with a pathotype carrying different virulence factors.

Cultivars within Group 13 were highly resistant. Isolate WBRS-96-1 was cultured from an infected field crop of cv. Caxton sampled early in the winter of 1995. It failed to infect cv. Caxton in 1996 field tests. Cultivar Caxton carries an adult plant resistance which would not have been effective at the growth stage of the plants from which the sample was collected.

CONTROLLED ENVIRONMENT TESTS

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

WBR-347-77
WBR-1947-77 Sa Ba

and following incubation in dew simulation chambers, were transferred to either of two post-inoculation environments, a low temperature regime (10°C and 12 h photoperiod) and a high temperature regime (25°C and 16 h photoperiod). The isolates were received from Dr Pavel Bartoš, Czech Republic and were virulent on seedlings of cv. Promessa in tests carried out by him.

Results

These are given in Table 5. The majority of the cultivars expressed high levels of resistance to the isolates. Assessments of flag leaf infection were made on reaction type and classified on the standard 0-4 scale as resistant (R = 0-2) or susceptible (S = 3-4) and were made 10 days post-inoculation at 25°C and 26 days post-inoculation at 10°C. Cultivars were generally selected on the basis of the high levels of resistance shown in previous tests.

Virulence to seedlings of cv. Promessa carried by the isolate WBR-347-77 was not confirmed in the adult plant tests although very low levels of a 3 type reaction (susceptible) were evident at 25°C. Isolate WBR-1947-77 Sa Ba failed to infect cv. Promessa in both the seedling and adult plant tests.

The majority of the cultivars were resistant, although in some inoculated with isolate WBR-347-77 it was less readily expressed at the higher temperature regime with cultivars displaying low levels of a 3 type reaction (susceptible). Several of these cultivars were classified as susceptible in seedling tests with the same isolate.

Cultivars Spark and Hereward carry resistance(s) which is effective at the lower temperature only to some isolates. Isolates have been identified which overcome this resistance but have remained at a low frequency. In these tests cv. Spark was susceptible to isolate WBR-347-77 as was cv. Hereward at 25°C but which expressed a mixed mainly resistant reaction at 10°C. Previous tests have suggested that these cultivars carry a common resistance but it may be that cv. Hereward carries additional resistance effective against some isolates, as it has also previously been less heavily infected in field nurseries to certain isolates (Jones and Clifford, 1995). Cultivars Fury and Charger carry adult plant resistance which was effective at 10°C only, whilst cv. Cadenza also carries a low temperature resistance effective against these isolates.

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Table 4. †Percentage infection of spring and winter wheat cultivars to specific isolates of *Puccinia recondita* in field isolation nurseries in 1996

Cultivar (NIAB rating)		Group	WBR factor	Isolate		
				WBRS-95-19	WBRS-96-1	WBRS-94-50
Clement		1	1	4	0.1	0
Rialto	(4)	1b		0	0	0
Slejpner		1c	1+APR	0	0	0
Hunter	(8)	1d	1+APR+OR	0	0	0
Fundin		2	2	17	5	6
Hobbit			2+	5 MS	1 MS	0.5
Norman			2+	6	2 MS	2
*Sappo		3	3	34	10	25
*Halberd		4	4	0	0	0
Huntsman		5	5 APR	25	15	13
Mercia	(4)		APR	21	12	7
Armada			0	26	19	9
Gamin		6	6 APR	0	0	0
Dynamo	(7)		APR	0	0	0
Virtue			APR	0	0	0
Sterna		7	7	0	0	0
Sabre			7	0	0	0
*Chablis	(9)		7	Trace	0	0
*Shiraz	(9)		7+ ?	0	0	0
Ranger		8	8 APR	0	0	0
Avans	((3))		OR ?	0	0	0
Kinsman				0	0	0

Table 4. (continued)

Cultivar (NIAB rating)		Group	WBR factor	Isolate		
				WBRS-95-19	WBRS-96-1	WBRS-94-50
Avalon		9	9 APR	Trace	0	0
Buster	(3)		APR	0.2	0	0
Riband	(4)			1	0.2	0
*Taffeta			APR	0	0	0
Spark	(8)	10	APR	0	0	0
Hereward	(7)		APR	0	0	0
Consort	(6)		APR	0	0	0
Soissons	(3)	10a	APR	Trace	0	Trace
Brigadier	(9)	11	OR	0.3	0	0
Hussar	(8)		OR	0	0	0
Beaufort	(9)		OR ?	0	0	0
Cadenza	(8)	11a		0	0	0
Flame	(8)		APR	0	0	0
*Imp	(4)	12	APR	0	0	0
*Minx			APR	0	0	0

Table 4. (continued)

Cultivar (NIAB rating)		Group	WBR factor	Isolate		
				WBRS-95-19	WBRS-96-1	WBRS-94-50
Genesis		13	APR	0	0	0
CWW93/2				0	0	0
Drake	(9)		OR	0	0	0
Harrier	(9)		OR	0	0	0
Madrigal	(9)		OR	0	0	0
Magellan				0	0	0
Encore	(9)		APR+OR	0	0	0
Raleigh				0	0	0
Caxton	(8)		APR	0	0	0
Reaper	(9)			0	0	0
CPW25			OR	0	0	0
Charger	(5)			0	0	0
*Promessa	(9)		OR	0	0	0
*Baldus	(7)		APR+OR	0	0	0
*Canon	(6)		APR+OR	0	0	0
*Axona	(9)		APR	0	0	0
*Ebony	(R)		OR	0	0	0
Chianti				0	0	0
*Palermo	(6)		APR	0.1	0	0
Crofter	(4)		OR	0.3	0	0
*Fury	(VS)			4	0	0.3

† Mean of 3 replicates, 2 assessment dates. All reaction types susceptible unless stated.
MS = mixed susceptible; APR = adult plant resistance; OR = overall resistance.
( ) NIAB rating: 1 = susceptible; 9 = resistant.

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

Isolate	WBR-347-77 (WBV-6)		WBR-1947-77 Sa Ba (WBV-6)	
Incubation Temperature °C				
Cultivar	10	25	10	25
Hunter	R	R	R	R
Madrigal	R (R)	R (R)	R (R)	R (R)
Encore	R	R	R	R
Harrier	R (R)	R (R)	R (R)	R (R)
Beaufort	R	R	R	R
Hussar	R (R)	R (R)	R (R)	R (R)
Brigadier	R (MR)	R (MR)	R (MR)	R (MR)
Rialto	R	R	R	R
Crofter	R (R)	R (MR)	R (R)	R (MR)
*Axona	R	MR	R	R
*Imp	R	MR	R	MR
Consort	R	MR	R	R
*Baldus	MR	MR	R	R
Dynamo	MR	MR	R	MR
*Shiraz	R (R)	MR (S)	R (MR)	R (MR)
*Chablis	R (S)	MR (MS)	R (S)	R (MR)
*Ebony	R (MR)	MR (MS)	R (MR)	R (MS)
*Promessa	R (MS)	MR (MS)	R (R)	R (R)
*Avans	R (S)	MR (MS)	R (MS)	-(MS)
*Palermo	R (S)	MR (S)	R (S)	MR (S)
Spark	MS	S	R	MR
Hereward	MR	MS	MR	MR
Caxton	R (S)	MS (S)	R (S)	R (S)
Fury	R (MS)	S (S)	R (S)	S (S)
Cadenza	MR	MS	MR	MS
Charger	MR (S)	MS (S)	R (S)	MS (S)
Armada	S	S	S	S

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

BROWN RUST OF WHEAT: NIAB ADULT PLANT TESTS

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METHODS

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

Table 1. Isolates of wheat brown rust used in adult plant tests, NIAB Cambridge, 1996

Isolate (Probable virulence)	Origin of isolate
WBRS-91-67 (1,2,Virtue,Buster)	Virtue, Cambs., 1991
WBRS-93-84 (2,5,9,Virtue, Buster)	Buster, Avon, 1993
WBRS-93-87/1 (1,2,5,9,Virtue)	Hereward, Cambs., 1993
WBRS-94-50 (1,2,6?)	Flame, Norfolk, 1994

RESULTS

In Table 2, cultivars have been grouped according to their response to infection by four, two or one of the isolates. This does **not** imply that cultivars in the same group possess a common resistance factor/s.

A major problem was encountered in 1996 in establishing a satisfactory level of infection. Despite successive inoculations and incubation, hot dry weather prevented disease development in most cultivars and thus this year's results should be interpreted with caution.

Mercia was the only cultivar to be infected by all four isolates, reflecting its increasing susceptibility to current races of brown rust in recent years (Clarkson & Mann, 1996). Buster was found to be susceptible to isolates 91-67 and 93-84. Otherwise, only seven other cultivars exhibited any infection, this being to isolate 91-67, which was less virulent than 93-84 in 1995 tests. Isolate 94-50, which had previously infected many cultivars in controlled environment (Jones & Clifford, 1995) and field (Jones & Clifford, 1996) tests, did not repeat this effect in these or IGER (Jones & Clifford, 1997) field tests in 1996.

The remaining thirty cultivars were not infected by any of the four isolates. These results do not necessarily imply that a cultivar is resistant, particularly as known susceptible cultivars such as Riband and Soissons also uncharacteristically failed to develop brown rust symptoms.

Table 2. Reactions of winter wheat cultivars to infection by four brown rust isolates in spreader bed tests, NIAB Cambridge, 1996. (Newer varieties in *italics*.)

		% Infection with brown rust by isolates:			
Cultivar	**(NIAB rating)***	**91-67**	**93-84**	**93-87/1**	**94-50**
Mercia	(4)	14.1	17.4	18.5	13.6
Buster	(3)	4.4	4.4	0	0
Haven		6.5	0	0	0
Rialto	(4)	3.3	0	0	0
Crofter		1.4	0	0	0
Beaufort	(9)	0.1	0	0	0
Slejpner		0.1	0	0	0
Abbot	(9)	0.1	0	0	0
Shango		0.1	0	0	0

The following cultivars showed **NO** infection:-
Avalon, Brigadier (9), Cadenza (8), Caxton (8), Charger ((5)), Chianti, Consort (6), *Drake*, Dynamo (7), Encore (9), *Equinox* (9), Flame, Genesis, *Harrier*, Hereward (7), Hunter (8), Hussar (8), *Impala*, *Madrigal* (9), *Magellan*, *Malacca*, Pastiche, *Raleigh*, Reaper (9), Riband (4), *Ritmo*, Soissons (3), Spark (8), Virtue, *Vivant*.

* For NIAB 1997 Recommended List varieties only; 1-9 scale: higher values indicate increasing resistance.

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MILDEW OF BARLEY

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Virulence factors corresponding to resistance factors of current barley cultivars were again recorded at high levels. *Mlo* resistance continues to be very effective against barley powdery mildew. The mildew population continues to increase in complexity, with more than 80% of isolates carrying seven or more virulence factors. The population remains heterogeneous, the most frequently occurring pathotype being recorded in less than 10% of the samples.

INTRODUCTION

The virulence survey for barley powdery mildew continued to monitor infection on new and existing cultivars in NIAB Recommended List trials and to determine changes in virulence frequencies in the fungal population.

Rainfall levels were low during the spring and early summer of 1996, the cool, dry weather in March and April encouraging initial build up and spread of powdery mildew. By May, infection was widespread and reached high levels on untreated plots. The continuing dry weather in June resulted in many samples of freshly sporulating mildew being received.

METHODS

Single colony isolates taken from 148 of the 210 samples collected from infected leaves were tested to determine virulence factors. 38 of the samples failed to produce viable conidia, while a further 26 samples were not tested. Single colony isolates were also obtained from plants of cv. Golden Promise exposed on a high roof at NIAB, Cambridge.

Isolates from infected leaves were collected from the following 11 locations:

NIAB, Cambridge	68	isolates	Wye, Kent	14	isolates
Headley Hall, Yorks.	54		Little Clacton, Essex	14	
Morley, Norfolk	36		Harper Adams, Salop.	10	
Cockle Park, Northumb.	30		Dyfed, Wales	5	
Bridgets, Hants.	27		Spalding, Lincs.	2	
Fakenham, Norfolk	16				
			Total	276	

Isolates were collected from the following 15 spring and 25 winter cultivars:

<u>Spring cultivars</u>

Cork	15	isolates	Riviera	9	isolates	Dandy	2	isolates
Toddy	14		Delibes	8		Hart	2	
Charm	14		Felicie	7		Landlord	2	
Cooper	13		Prisma	7		Derkado	1	
Optic	12		Tyne	5		Draught	1	

Winter cultivars

Muscat	14 isolates	Gleam	7 isolates	Puffin	4 isolates
Regina	14	Manitou	6	Intro	4
Angora	13	Fighter	5	Fanfare	4
Rifle	11	Sunrise	5	Epic	4
Gaelic	10	Linnet	5	Sprite	3
Portrait	10	Halcyon	4	Tokyo	3
Spice	10	Hanna	4	Melanie	2
Prelude	8	Pipkin	4	Pastoral	2
Falcon	8				

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

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

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

RESULTS

Virulence

The results of the 1996 survey are shown in Table 2. There were differences between the results obtained from the leaf samples and those from the airborne spore population, particularly those collected in March. This is probably explained by the relative contribution of winter and spring cultivars to the populations collected. The airborne spores sampled in March are the result of infections selected by, and maintained on, winter cultivars in which

the diversity of resistance factors is low. Later in the season, spring cultivars have influenced selection and many leaf samples were derived from infection on these cultivars.
Virulence for *Mlh, Mlg* and *Ml(CP)* continued at a high level, while *Vra* remained at 100%. *Va6* and *Va12* were lower in the March roof sample, although there is some selection for these virulence factors in winter cultivars. Levels of *VLa* showed a large increase from March to October, with the June sample giving similar results to the leaf samples. This probably reflects the selection pressure on spring cultivars, some of which possess *Ml(La)*, during the summer. The levels of *Vk1* were consistent in all samples: there is currently no selection for this virulence factor. *Va7* remained high in the populations, although there is now little selection for this factor. The low value for *V(Ab)* in June is unexplained as several spring cultivars carry the corresponding resistance. *Va9* and *Va13* were highest in the March sample, due to selection by the winter cultivars Manitou and Pipkin respectively. *Va3* remained present at a very low level in the population.

Table 2. Virulence frequencies in single colony isolates of barley mildew from infected leaves (leaf sample) and from random samples of airborne spores.

		Frequency of virulence factors (%)				
		Leaf sample		Random samples of airborne spores		
Virulence gene	Virulence factor	All data	Non-corresponding virulence *	March	June	October
Vh	1a	83	79	77	61	67
Vra	1b	100	100	100	100	100
Vg	2a	98	98	87	98	88
V(CP)	2b	93	93	81	88	86
Va6	3	36	32	19	14	31
VLa	4	58	54	33	51	78
Va12	5	75	75	52	61	67
Vk1	6a	77	76	75	73	76
Va7	6b	79	79	62	65	90
V(Ab)	6c	68	63	56	39	57
Va1	7	47	40	12	31	25
Va9	8	38	32	40	29	31
Va13	10	36	34	73	41	35
Va3	11	1	1	4	0	0
Number of isolates		276		52	51	49

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

There was little difference between the data from all leaf isolates and the virulence frequency derived from cultivars lacking the corresponding resistance factors. This suggests the occurrence of most virulence factors on all cultivars, whether or not the corresponding resistance is present.

Table 3 compares the results of the 1996 survey with those from the preceding five years. Frequencies of most of the virulences factors examined have remained constant during this period. Following an earlier increase, *V(Ab)* now appears to be declining.
V(La), Va1 and Va9 have all increased since 1991, following the introduction of cultivars possessing the corresponding resistances, such as Cooper (*Ml(La), Mla1*), Cork (*Mla1, Ml(Ab)*), Felicie (*Mlg,Mla9*) and Manitou (*Mla9*).

Table 3. Virulence frequencies in barley mildew, 1991 to 1996.

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

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

- No data

Complexity of isolates

Table 4 illustrates the complexity of the barley mildew population, expressed as the number of isolates carrying increasing numbers of virulence factors. The majority of isolates tested in 1996 carried seven or more virulence factors. The most complex isolates were derived from the leaf samples, two isolates having thirteen virulence factors.

Table 5 compares the complexity of isolates tested since 1991. There continues to be an increase in the complexity of isolates. In 1993, only 15% of the isolates tested had more than seven virulence factors, but this number rose to 59% in 1994, 64% in 1995, with a further increase to 88% in 1996.

Table 4. Number of virulences carried by isolates of barley mildew in 1996

No. of virulence factors	Frequency of isolates with each number of virulences*			
		Random samples of airborne spores		
	Leaf samples	March	June	October
0	0	0	0	0
1	0	0	0	0
2	0	0	2	0
3	1	2	0	0
4	1	0	2	4
5	1	8	6	2
6	6	8	16	8
7	11	23	22	14
8	20	29	24	22
9	25	23	20	24
10	19	23	10	16
11	11	6	0	8
12	4	2	0	0
13	1	0	0	0
No. of isolates	276	52	51	49

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

Table 5. Comparison of the complexity of isolates collected in 1991 to 1996.

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

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

Frequencies of the most common pathotypes

The frequencies of the most common pathotypes found in the 1996 samples are shown in Table 6. The trend towards a more complex pathogen population continued, with a larger number of pathotypes carrying more virulence factors being recorded albeit at lower levels.

Table 6. Frequencies of the most common barley mildew pathotypes identified in 1996, defined by *Vh*, *Vra*, *Vg*, *V(CP)*, *Va6*, *VLa*, *Va12*, *Vk*, *Va7*, *V(Ab)*, *Va1*, *Va9* and *Va13*.

	Frequency of pathotypes (%)			
		Samples of airborne spores		
Pathotypes *	Leaf sample	March	June	October
Va6 Va12 Vk1 V(Ab)	<1	0	0	0
Va12 Va7 V(Ab)	1	2	4	0
Va12 Vk1 Va7 V(Ab)	4	0	2	0
Va6 Va12 Va7 V(Ab)	4	1	1	0
Va6 Va12 Vk1 Va7 V(Ab)	3	2	1	4
Va6 Va12 Va7 V(Ab) Va1	5	0	1	0
Va12 Vk1 Va7 V(Ab) Va1	2	0	0	4
Va6 Va12 Vk1 Va7 V(Ab) Va1	3	0	3	0
Va6 V(La) Va12 Vk1 Va7 V(Ab) Va1	2	0	3	0
Vk1 Va7 V(Ab) Va13	2	2	3	2
Va12 Vk1 Va7 V(Ab) Va13	2	3	1	0
Va6 Va12 Vk1 Va7 V(Ab) Va13	2	1	1	0
Total number of pathotypes	173	75	61	41
Total number of isolates	332	97	73	50

* All pathotypes also carry *Vra*, *Vg* and *V(CP)*, and most carry *Vh*.

Table 7 shows the proportion of the barley mildew population sampled in 1996 which was able to infect the cultivars in Recommended List trials. Many of the winter cultivars, such as Hanna and Pastoral, have no effective resistance and this is reflected in their low NIAB ratings. Halcyon, Sprite and Intro also have no effective specific resistance but, as their NIAB rating illustrates, possess some non-specific resistance. Epic carries specific resistance, virulence for which occurred in only 27% of the population.

Of the spring cultivars, Optic and Prisma were susceptible to 21% of the population. However, Optic carries good no-specific resistance (NIAB rating 3). Tyne and Cooper (both NIAB rating 7) were susceptible to less than 30% of the population. Virulence corresponding to the mlo resistance in cultivars such as Alexis, Chariot and Derkado was absent from the population.

Table 7. The proportion of mildew isolates tested in 1996 able to infect the barley cultivars in Recommended List trials (NIAB rating for mildew in brackets)

Winter cultivars	Proportion (%)	Winter cultivars	Proportion (%)
Hanna (4)	100	Angora (5)	78
Halcyon (6)	100	Rifle (8)	70
Intro (6)	100	Regina (3)	70
Linnet (4)	100	Puffin (6)	55
Muscat 5)	100	Pipkin (2)	41
Pastoral (3)	100	Manitou (5)	37
Sprite (6)	100	Gleam (6)	30
Fanfare (5)	90	Epic (8)	27
Melanie (5)	78	Sunrise (5)	26
Spring cultivars	**Proportion (%)**	**Spring cultivars**	**Proportion (%)**
Optic (7)	51	Chariot (9)	0
Prisma (3)	51	Dandy (9)	0
Felicie (8)	33	Derkado (9)	0
Delibes (6)	28	Hart (9)	0
Cooper (7)	22	Landlord (9)	0
Tyne (7)	18	Tankard (9)	0
Alexis (9)	0		

Fighter and Gaelic are not included in Table 7 since their resistance factors, and hence the corresponding virulence, remain unknown.

Resistance factors in new cultivars

The resistance genes in cultivars included in the Barley Mildew Variety Diversification Scheme and in UK Recommended List candidates tested in 1996 are given in Table 8.
Data from earlier tests suggested that Charm may carry *Ml(La)*, *Mlk1*, *Mla9*, but further tests contradicted this. All isolates were tested on both Charm and Toddy; of 38 isolates virulent on Charm, all carried *Vk1* and *Va9* but four lacked *V(La)*. It seems likely that Toddy carries *mlo* resistance, possibly with *Ml(Ab)*, as typical infection included a reduced number of colonies with infection type 4. This would be consistent with its parentage which includes Optic (*Mla12,Ml(Ab)*) and Chariot *(mlo)* .

Table 8. Specific resistance genes of barley cultivars.

None	*Mlh,Mlg,Ml(CP),Mla12*	*Mlg,Ml(CP),Mla12,Ml(Ab)*
Halcyon (W)	Spice (W)	Prisma (S)
Hanna (W)		
	Mlra,Mlg,Ml(CP),Mla12	*Ml(La),Mla1*
Mlra	Falcon (W)	Cooper (S)
Intro (W)		
Linnet (W)	*Mlh,Mlra,Mlg,Ml(CP),Mla12*	*Ml(Ab),Mla1*
Pastoral (W)	Puffin (W)	Brewster (S)
Sprite (W)		Chad (S)
Muscat (W)	*Mla9*	Cork (S)
Tokyo (W)	Manitou (W)	Delibes (S)
Mlh,Mlra	*Mlg,Ml(CP),Mla9*	*mlo*
Angora (W)	Felicie (S)	Alexis (S)
Melanie (W)		Chariot (S)
	Mla13	Dandy (S)
Mlra,Mlg	Pipkin (W)	Derkado (S)
Fanfare (W)	Camargue (S)	Hart (S)
Mlh,Mlra,Mlg,Ml(CP)	*Ml(La),Mla13*	*mlo?*
Prelude (W)	Tyne (S)	Draught (S)
Portrait (W)		Landlord (S)
	Ml(Ab),Mla9	Tankard (S)
Mlra,Mlg,Ml(CP),Mla6	Nomad (S)	
Epic (W)		Uncertain
	Mla9+?	Fighter (W)
Mlh,Mlra,Mlg,Ml(CP),Mla6	Charm (S)	Gaelic (W)
Sunrise (W)		Riviera (S)
Gleam (W)	*Mla12,Ml(Ab)*	Toddy (S)
	Optic (S)	
Mlra,Mla12		
Regina (W)		
Rifle (W)		

(W) winter cultivar, (S) spring cultivar

DISCUSSION

Virulences corresponding to resistance factors in current cultivars occurred at high levels, including populations taken from cultivars lacking the corresponding resistance. Some virulence factors for which there is presently no selection also continued to occur at high levels. The complexity of the mildew population continued to increase, with two isolates carrying thirteen virulence factors. As in previous years, no single pathotype dominated the populations sampled and the barley powdery mildew population continues to be heterogeneous. All current resistance factors are matched by corresponding virulence factors, with the exception of *mlo*. There continues to be an increasing dependence on *mlo* for resistance to powdery mildew in spring barley cultivars. Although the current winter barley cultivars have little effective specific resistance, some have good non-specific resistance to mildew.

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MILDEW OF BARLEY IN NORTHERN IRELAND

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The frequencies of most of the major genes and combinations thereof have remained at similar levels to those encountered in previous seasons, including the continued resistance of *mlo*. Two exceptions were the sudden unexplained drop in *Va1* and an increase in the *Vla, Va13* combination, possibly reflecting the earlier popularity of *cv.* Tyne.

Forty isolates were obtained during the year using Golden Promise trap plants, 20 from winter barley and 20 from spring barley crops - cultivars of the crops from which they came are indicated in Table 1. The cultivars used for testing virulences of isolates and their genetic designations, are shown in Table 3, while the most commonly sown cultivars in N.Ireland in the same season, 1995/96, are shown in Table 2. The percentage of spring cultivars carrying the *mlo* gene is down to 58% of the area sown compared with the previous total of 73%. The area down to Chad (*Ml(Ab), Mla1*) is now declining but still occupied 5% of the area in 1996.

Table 1. Sources of mildew isolates tested in 1996

Resistance gene(s)	Isolate source	No. isolates
none	Halcyon	1
none	Hanna	1
Mlra	Pastoral	7
Mla9	Manitou	7
mlo	Alexis	1
mlo	Dandy	5
Mlra, Mla6	Gaelic	1
Ml(Ab), Mla1	Chad	10
Mlg, Ml(CP), Ml(Ab)	Fighter	2
Mlg, Mlh, Ml(CP)	Puffin	1
Mlg, Ml(CP), Mla9	Felicie	4

Table 2. Percentage use of barley cultivars in N.Ireland (1995/96)

Spring cultivars (*resistance genes*)	%	Winter cultivars (*resistance genes*)	%
Dandy (*mlo*)	36	Fighter (*Mlg, Ml(CP), Ml(Ab)*)	45
Chariot (*mlo*)	22	Pastoral (*Mlra*)	40
Riviera (?)	20	Hanna (*none*)	10
Felicie (*Mlg, Ml(CP), Mla9*)	14	Manitou (*Mla9*)	4
Chad (*Ml(Ab), Mla1*)	5		
Hart (*Ml(Ab), Mla1*)	1		
Tyne (*MlLa, Mla13*)	1		

The frequencies of a range of single major genes and some of their combinations are shown in Table 4. While most of these have remained within a range consonant with previous values (Mercer, 1996) there were some exceptions. There was a completely unexplained drop in *Va1*

Table 3. Test cultivars for the detection of virulence groups

Cultivar	**Resistance gene**	**BMR group**
Golden Promise	none	0
Zephyr	*Mlg, Ml(CP)*	2
Midas	*Mla6*	3
Goldspear	*Mla6, MlLa*	3 + 4
Varunda	*MlLa*	4
Egmont	*MlLa, Mla12*	4 + 5
Dram	*MlLa, Mlk*	4 + 6a
Klaxon	*MlLa, Mlk, Mla7*	4 + 6a + 6b
Atem	*MlLa, mlo*	4 + 9
Tyne	*MlLa, Mla13*	4 + 10
Hassan	*Mla12*	5
Keg	*Mlk, Mla7*	6a + 6b
Triumph	*Mla7, Ml(Ab)*	6b + 6c
Delta	*Mla1*	7
Leith	*Mla9*	8
Digger	*Mla13*	10

Table 4. Frequencies of virulence alleles from isolates collected from barley crops from 1990-1996

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

from 41% in the previous season (this was wrongly noted as 22% in the 1995 report). Although the percentage of corresponding host plants with susceptible lesions was high, there were few such lesions on any of the other diferentials. The old Atem combination (*VlLa, mlo*) continues to maintain its clean record, but the Tyne combination (*VlLa, Vla13*) has increased substantially over the previous season, perhaps reflecting the relatively large, though now declining area of Tyne over the last few years.

Fungicide sensitivity testing was discontinued.

REFERENCE

Mercer, P (1996). Mildew of barley in Northern Ireland. *UK Cereal Pathogen Virulence Survey 1994 Annual Report*, 44-46.

YELLOW RUST OF BARLEY

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No samples were received in 1996. Seedling tests confirmed the virulence factors in 12 isolates selected from 1974-1994 and the resistance genes in winter and spring recommended cultivars. Adult plant tests in field spreader beds demonstrated a wide range of resistance and showed that susceptible cultivars represent a potential risk if widely grown.

1996 ISOLATES

No samples were received in 1996. This reflected the occurrence of severe frosts during the winter and hot, dry conditions during spring and summer.

VIRULENCE FREQUENCIES FOR 1981-1996

The specific resistances (BYR factors) identified in barley cultivars to date, differential cultivars possessing each resistance and the year of first detection of corresponding virulence in the UK population of *P.striiformis* are given in Table 1.

Table 1 Resistance factors to *Puccinia striiformis* and differential cultivars

BYR Factor	Type*	Differential Cultivars	BYV detected
BYR 1	O	Astrix, Atem	1960
BYR 2	O	Bigo, Varunda	)
			) 1972-1975
	S	Mazurka	)
BYR 3	?S	Triumph	1983

* O = Overall, S = Seedling. Overall resistances are effective at all growth stages, seedling resistances are ineffective at adult plant growth stages.

Virulence frequencies for 1981-96 are given in Table 2.

Table 2 Virulence factor frequency (%)

	'81	'82	'83	'84	'85	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96
BYV 1	100	100	100	100	-	-	100	-	100	100	100	100	100	100	100	-
BYV 2	81	96	87	100	-	-	100	-	100	0	100	100	100	100	100	-
BYV 3 †	-	-	17	86	-	-	22	-	75	0	0	0	0	100	0	-
Number of isolates	52	25	30	7	0	0	9	0	4	1	1	2	1	1	3	0

† Not included in tests before 1983.

SEEDLING TESTS

Eighteen winter and thirteen spring recommended cultivars were tested together with standard differentials against twelve isolates selected from 1974-1994 (Table 3A).

Seedling samples were tested using methods described by Priestley, Bayles and Thomas (1984). Results are given in Table 3A.

Winter barleys

Thirteen cultivars were susceptible to all isolates and appeared to possess no specific resistance. However, these cultivars showed a range of infection levels in adult plant tests (Table 3), i.e. Regina (21.5%), Gleam (6.0%), Epic (2.8%), Pastoral (1.3%). Fighter and Halcyon carried BYR factor 1 with adult plant tests indicating disease levels of 8.5% and 7.5% respectively. Manitou, Fanfare and Puffin gave inconsistent reactions in seedling tests and their resistances, if any, could not be identified. Adult plant infection levels for these cultivars were 14.8%, 9.5% and 3.3% respectively.

Spring barleys

Five cultivars possessed no specific resistance, but showed a range of infection levels on adult plants, i.e. Hart (10.5%), Felicie (8.7%), Landlord and Tankard (3.8%), Chariot (1.2%).

Riviera and possibly Dandy possess BYR factor 1. Alexis and Prisma which share the common parent Trumph possess BYR factor 3.

Delibes and Derkado, which were resistant to all isolates in seedling tests, also had high levels of adult plant resistance, i.e. Delibes (1.0%), Derkado (0.1%). Their resistance appears to be unmatched by current BYV factors in the UK.

Cooper and Optic gave inconsistent reactions in seedling tests and their resistances, if any, could not be identified.

ADULT PLANT TESTS IN SPREADER BEDS

Twenty-one winter and fifteen spring barley cultivars were sown in mixed isolate beds sown in the winter, and spring respectively.

The nurseries were inoculated with a mixture of the following isolates of *P.striiformis*.

Isolate	**Virulence**
84/2	BYV 1,2
83/38	BYV 1,2,3

Results are given in Table 3.

Table 3 Adult plant tests 1996. Mean per cent leaf area infection (mean of 3 assessments x 2 replicates).

Winter Barley			**Spring Barley**		
Cultivar	BYR Factor	%	**Cultivar**	BYR Factor	%
Regina	0	21.5	Hart	0	10.5
Angora	0	20.0	Riviera	1	9.7
Melanie	0	15.3	Alexis	3	8.7
Manitou	Rx	14.8	Felicie	0	8.7
Muscat	0	12.0	Prisma	3	4.7
Linnet	0	11.8	Tyne	-	4.5
Sprite	-	11.8	Landlord	0	3.8
Intro	0	11.5	Tankard	0	3.8
Hanna	0	10.5	Cooper	Rx	3.2
Fanfare	Rx	9.5	Dandy	1?	1.7
Gaelic	0	9.0	Cork	-	1.4
Fighter	1	8.5	Chariot	0	1.2
Halcyon	1	7.5	Delibes	R	1.0
Pipkin	0	7.3	Optic	Rx	0.8
Gleam	0	6.0	Derkado	R	0.1
Rifle	0	4.0			
Puffin	Rx	3.3			
Sunrise	-	3.3			
Epic	0	2.8			
Prelude	-	2.0			
Pastoral	0	1.3			

- = cultivars no longer recommended not included in seedling tests.

Winter barleys

High levels of infection developed on susceptible cultivars. Angora, Melanie and Regina developed particularly high infection levels. These cultivars have yellow rust resistance ratings of 3,2,2 respectively and are equal or below the minimum standard of 3, demonstrating their epidemic risk.

REFERENCE

Priestley, R H, Bayles, R A and Thomas, J E (1984). Identification of specific resistances against *Puccinia striiformis* (Yellow rust) in winter wheat varieties I. Establishment of a set of type varieties for adult plant tests. Journal of the National Institute of Agricultural Botany, 16, 469-476.

Table 3A Average infection types of winter and spring cultivars tested with isolates from 1974 - 1994

	BYR	74/33	75/37	89/4	82/13	75/101	80/32	80/47	84/2	81/31	83/38	83/39	94/4
	factors	0	0	0	1	1,2	1,2	1,2	1,2	1,2,3	1,2,3	1,2,3	1,2,3
Differentials													
Astrix	1	0.0	0.1	0.0	4.0	3.4	4.0	4.0	4.0	4.0	2.9	4.0	4.0
Atem	1	0.0	0.6	0.0	4.0	3.6	2.6	3.7	2.9	4.0	2.9	4.0	4.0
Mazurka	2	0.0	0.4	0.0	0.8	3.9	3.8	2.0	3.9	2.7	2.8	3.4	3.5
Varunda	2	0.0	0.8	0.0	0.5	3.9	4.0	3.6	3.9	3.3	3.3	4.0	3.6
Triumph	3	0.0	0.5	0.0	0.6	0.0	0.1	0.2	0.5	3.1	2.1	3.8	2.9
Winter													
Fighter	1	0.9	1.6	1.8	4.0	3.8	4.0	3.7	3.0	4.0	2.7	4.0	4.0
Halcyon	1	0.4	0.6	1.0	4.0	4.0	4.0	3.3	4.0	4.0	2.9	4.0	2.3
Fanfare	Rx	3.6	0.5	1.5	0.8	3.5	4.0	3.7	2.9	4.0	4.0	4.0	2.9
Manitou	Rx	0.6	3.9	2.5	0.7	3.8	4.0	4.0	2.9	4.0	4.0	4.0	3.8
Puffin	Rx	1.3	0.0	1.3	4.0	0.3	0.8	1.6	0.0	1.4	0.4	4.0	0.5
Epic	0	3.8	4.0	3.8	4.0	4.0	4.0	4.0	2.9	4.0	4.0	4.0	4.0
Gaelic	0	4.0	3.7	4.0	4.0	4.0	3.8	4.0	3.7	4.0	3.0	4.0	4.0
Intro	0	4.0	3.6	4.0	4.0	3.9	4.0	4.0	4.0	4.0	3.0	4.0	4.0
Linnet	0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	3.8	4.0	3.0	4.0	4.0
Pastoral	0	3.6	4.0	3.8	4.0	3.9	4.0	4.0	3.8	4.0	3.0	4.0	4.0
Hanna	0	4.0	4.0	3.7	4.0	3.7	4.0	4.0	2.9	4.0	4.0	4.0	4.0
Pipkin	0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Melanie	0	3.7	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Rifle	0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Gleam	0	3.7	4.0	3.6	4.0	4.0	4.0	4.0	3.8	4.0	4.0	4.0	4.0
Muscat	0	3.6	4.0	3.7	4.0	4.0	4.0	4.0	3.8	4.0	4.0	4.0	4.0
Regina	0	2.9	4.0	4.0	4.0	4.0	4.0	4.0	3.6	4.0	4.0	4.0	4.0
Angora	0	3.2	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Spring													
Riviera	1	0.0	0.3	0.0	3.7	2.6	4.0	3.8	4.0	4.0	4.0	4.0	4.0
Dandy	1?	0.0	1.4	3.0	4.0	3.7	2.9	3.4	1.2	4.0	3.3	4.0	4.0
Prisma	3	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	2.9	4.0	3.7
Alexis	3	0.2	0.0	0.0	0.5	0.0	1.5	1.4	0.0	2.7	2.8	4.0	3.8
Delibes	R	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.3	0.3	0.8	0.5
Derkado	R	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0
Cooper	Rx	0.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	4.0	4.0	1.0
Optic	Rx	0.0	0.8	0.0	1.0	0.3	0.0	4.0	0.0	3.9	4.0	0.6	0.3
Chariot	0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Felicie	0	4.0	4.0	0.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Hart	0	0.3	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Landlord	0	4.0	4.0	4.0	4.0	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
Tankard	0	4.0	3.7	4.0	4.0	0.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0

Average infection types : >2.0 =susceptible, ≤ 2.0 = resistant

BROWN RUST OF BARLEY

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Seedling tests with 1996 isolates identified virulence factor BBV-3 at similar levels in the population to 1995 when it showed an increased frequency. Glasshouse adult plant tests identified some winter barleys as carrying effective resistance to the isolates tested, with a number of spring barleys having adult plant resistance. Concern that some cultivars showed higher than expected disease levels at some sites in 1996 may be partly explained by the increased incidence of BRV-3 pathotypes, whilst a possible increase in virulence to some other cultivars requires monitoring.

GLASSHOUSE SEEDLING TESTS WITH 1996 ISOLATES

Of the seventeen samples of barley brown rust received in 1996, thirteen were collected from a range of winter barley cultivars. The remainder came from a spring barley trial grown at a single site. One sample was sent from the CSL/ADAS Cereal Disease Survey. The geographic origins of the samples are given in Table 1.

Table 1. Geographical origin of 1996 barley brown rust samples

Location (MAFF region)	Number of samples
West Midlands	15
East Anglia	1
Wales	1

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

Virulence combinations (races) identified from the 1996 isolates are given in Table 3. Some of the octal numbers of the isolates have not been assigned to isolates in previous seasons. This is because Hordeum 2596, which has replaced C.I.1243 as the Pa_9 donor, appears to be more resistant to some isolates than C.I.1243 the resistance of which is temperature-sensitive.

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

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

Table 3. Races identified from 1996 isolates

Number of isolates	Octal designation	BBV factors
4	273	1,2,4,5,6,8
1	673	1,2,4,5,6,8,9
1	1273	1,2,4,5,6,8,10
1	1653	1,2,4,6,8,9,10
3	1677	1,2,3,4,5,6,8,9,10
1	677	1,2,3,4,5,6,8,9
1	1657	1,2,3,4,6,8,9,10

The increased frequency of isolates carrying virulence to BBR-3 in 1995 was confirmed with 50% of the 1996 isolates virulent on Estate (Pa_3). This resistance has seldom been deployed in commercial varieties in the UK but seedling and adult plant tests in 1996 with specific isolates of *P. hordei* (Tables 5 and 6) suggest that the spring barley Alexis and a small number of other spring barleys may carry BBR-3.

GLASSHOUSE ADULT PLANT TESTS

Adult Plant Tests:

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

Race octal	BBV
1677	1,2,3,4,5,6,8,9,10
1653	1,2,4,6,8,9,10
273	1,2,4,5,6,8

The plants were inoculated by spraying with a spore suspension. They were placed in dew chambers for 16 h at 15°C post-inoculation and then incubated in the glasshouse at approximately 15°C for 14 days. Assessments were made of the percentage area of the flag leaf infected and of infection type.

Seedling Tests:

Seedlings of the cultivars, grown to the second leaf stage, were inoculated with the same isolates and incubated under the same conditions as the adult plants. Seedling x isolate interactions were classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4).

Results

Seedlings of the winter barleys were all susceptible (Table 4) to the three isolates. Infection levels on the adult plants were generally higher on cultivars inoculated with race octal 273, with the majority of the cultivars being susceptible. The high levels of infection recorded on cvs Prelude, Hanna and Fanfare should be interpreted with caution as assessments of infection levels were not made on the flag leaf due to the failure of the cultivars to develop beyond the vegetative phase. A second group of cultivars expressed high levels of resistance (confirming their NIAB disease ratings) to the isolates although cvs Spice, Portrait and, to a lesser degree, Gaelic were more susceptible to race octal 273, which is the simplest of the three races.

The spring barleys (Table 5) expressed a range of quantitative responses to the isolates. The cultivars are grouped within the table on the basis of similarities in their responses, particularly as adult plants, to the isolates.

Group 1: Cultivars susceptible.

Group 2: Cultivar Simon (BBR-3) was susceptible to race octal 1677 which was the only isolate carrying the corresponding virulence factor BBV-3). Cultivar Alexis showed a similar pattern of responses suggesting that it also carries this resistance. Also placed in this group are cvs Cork and Charm although they are seedling susceptible to race octal 1653.

Group 3: Races octal 1677 and 1653 which carry BBV-10 were virulent on cv. Triumph (BRR-10). Cultivar Prisma was also susceptible to these two isolates.

Group 4: Cultivars Felicie and Chariot expressed adult plant resistance to the widely virulent races octal 1677 and 1653, but displayed a mainly susceptible reaction to the simpler race octal 273. The majority of the other cultivars tested were resistant to this isolate as seedlings and adult plants.

Group 5: The adult plant resistance of these cultivars was effective against the three isolates, although they displayed a range of quantitative responses. Their resistances were also effective to isolate 273 in seedling tests.

The remaining cultivars were tested as seedlings only. Host:isolate interactions suggest that cvs Pitcher and Trinity should be placed in Group 5. Cultivars Scarlett, 4220.D.31 and Madras were resistant to race octal 1653 but susceptible to race octal 1677 suggesting that they may carry resistance factor BBR-3 in common with Group 2 varieties. The resistances of cvs Toddy, Livet and Spey were effective against the isolates to which they were tested.

Concern was expressed during the 1996 season at higher levels of brown rust on some spring barleys at certain trial sites than would be expected from their NIAB disease ratings. Unfortunately, no heavily infected samples were received from cultivars which were of concern but four samples with low infection levels (1%) were received from a single site at Newport, Shropshire. Isolates were cultured from two of these, Draught (BRS-96-5) and Landlord (BRS-96-6), and tested on seedlings and adult plants of the currently recommended spring barleys together with a number of varieties in N.L.2 trials, using procedures described previously.

Results

Infection levels were generally too low on the adult plants to make a quantitative assessment so host:pathogen interactions were classified on the standard 0-4 scale as resistant (R: 0-2) or susceptible (S: 3-4). Cultivars were grouped on the basis of their responses to the isolates (Table 6).

Group 1: Susceptible to both isolates.

Group 2: Cultivars Alexis, Charm and Cork appear to carry resistance factor BBR-3 as they are more susceptible to isolate BRS-95-6 which carries the corresponding virulence. They had also been more susceptible to a BBV-3 isolate in previous tests (Table 5). The responses of cvs 4220.D.31, Scarlett and Madras suggest that they also carry resistance factor BBR-3 thus supporting previous data (Table 5). These three cultivars together with cv. Alexis showed the largest discrepancies between their NIAB ratings and the rating assigned to them at various trial sites. It may be that the sites at which they were more heavily infected than expected were infected with rust carrying virulence factor BBV-3. Isolates carrying this virulence have been at a low frequency in the pathogen population over the years due to the resistance BBR-3 seldomly being exploited in UK varieties. It was reported in 1996 (Jones and Clifford) that the frequency of isolates carrying virulence factor BBV-3 had increased greatly in 1995. Isolates tested from the 1996 survey showed that this virulence was again at a similar frequency in the population.

Group 5: Other cultivars were also reported to be showing slightly higher levels of disease than would be expected from their NIAB disease rating. Among these were derivatives of cv. Chariot namely cvs Landlord, Draught, Tankard and Toddy. Cultivar Chariot has shown good levels of adult plant resistance in glasshouse adult plant tests in 1995 (Jones and Clifford, 1996) and in 1996 (Table 5) with the exception of an isolate of race octal 273 to which it expressed a mixed susceptible response. It had previously shown similar levels of infection to two isolates in field nurseries in 1993 (Jones and Clifford, 1994). In 1996 tests with isolates BRS-96-5 and BRS-96-6 it also expressed a mixed susceptible reaction, but with no quantitative assessment it is not possible to confirm increased virulence to cv. Chariot by these more recently sampled isolates.

Cultivars Landlord, Draught and Tankard were classified as being resistant at the adult plant growth stages in tests with the standard isolates (Table 5) and to isolates BRS-96-5 and BRS-96-6. The mixed response displayed by the cultivars in both tests did however appear to be of a more resistant type (mainly 1 and 2 type pustules with only a few 3 type) to the standard isolates than to the two 1996 isolates (2 and 3 type pustules, with a large number of type 3). It may be that the pathogen is overcoming the resistance conferred by cv. Chariot and the situation requires monitoring.

Other cultivars within Group 5 were generally more resistant to isolate BRS-96-5.

In summary it would appear that cvs Alexis, 4220.D.31, Scarlett and Madras carry resistance factor BBR-3. The higher than expected levels of disease on these cultivars at certain sites is probably due to the presence of BRV-3 pathotypes which have increased in frequency during 1995 and 1996. The resistance of some other cultivars, especially derivatives of cv. Chariot, may be becoming less effective and requires monitoring.

REFERENCES

Jones, E.R.L. and Clifford, B.C. (1996). Brown rust of barley. United Kingdom Cereal Pathogen Virulence Survey 1995 Annual Report, pp.52-55.

Jones, E.R.L. and Clifford, B.C. (1994). Brown rust of barley. United Kingdom Cereal Pathogen Virulence Survey 1993 Annual Report, pp.53-57.

Table 4. *Percent infection of adult plants and seedling reactions of winter barley cultivars to specific isolates of *Puccinia hordei* under glasshouse conditions

Isolate / Cultivar (NIAB rating)		Octal 1677 (BBV-1,2,3,4,5,6,8,9,10)		Octal 1653 (BBV-1,2,4,6,8,9,10)		Octal 273 (BBV-1,2,4,5,6,8)	
Prelude†	(8)	25	(S)	20	(S)	30	(S)
Hanna†	(7)	20	(S)	18	(S)	30	(S)
Fanfare†	(7)	20	(S)	20	(S)	30	(S)
Melanie	(4)	23	(S)	25	(S)	28	(S)
Sprite	(7)	25	(S)	20	(S)	28	(S)
Fighter	(6)	20	(S)	15	(S)	28	(S)
Angora	(3)	20	(S)	20	(S)	25	(S)
Tokyo		20	(S)	15	(S)	25	(S)
Manitou	(5)	20	(S)	13	(S)	28	(S)
Pastoral	(6)	20	(S)	15	(S)	20	(S)
Muscat	(7)	20	(S)	13	(S)	20	(S)
Halcyon	(7)	25	(S)	15	(S)	20	(S)
Gleam	(7)	15	(S)	15	(S)	23	(S)
Regina	(6)	15	(-)	10	(-)	20	(-)
Pipkin	(6)	20	(S)	15	(S)	13	(S)
Linnet	(8)	10	(S)	10	(S)	15	(S)
Epic	(8)	20 MS	(S)	23 MS	(S)	18 MS	(S)
Spice	(9)	1	(-)	1	(-)	10 MS	(-)
Rifle	(9)	10 MR	(S)	15 MR	(S)	10 MR	(S)
Portrait	(8)	1	(S)	0.1	(S)	10 MS	(S)
Gaelic	(8)	0	(S)	0	(S)	3 MS	(S)
Intro	(8)	0.3	(-)	2	(-)	0.5 MS	(-)
Puffin	(8)	0	(-)	0	(-)	5 R	(-)
Falcon		2 MR	(S)	0	(S)	10 R	(S)
Peridot	(9)	-	(S)	-	(S)	-	(S)
Baton	(8)	-	(S)	-	(S)	-	(S)
Jewel	(8)	-	(S)	-	(S)	-	(S)
Vertige	(6)	-	(S)	-	(S)	-	(S)
Spirit	(7)	-	(S)	-	(S)	-	(S)

*Percentage - mean of 2 replicates

†Disease assessment not made on flag leaf

All adult plant reactions susceptible unless stated

R = resistant MR = mixed resistant MS = mixed susceptible

S = susceptible ( ) seedling reaction

Table 5. *Percent infection of adult plants and seedling reactions of spring barley cultivars to specific isolates of *Puccinia hordei* under glasshouse conditions

Isolate / Cultivar (NIAB rating)		Group	Octal 1677 (BBV-1,2,3,4,5,6,8,9,10)		Octal 1653 (BBV-1,2,4,6,8,9,10)		Octal 273 (BBV-1,2,4,5,6,8)	
Dandy	(4)	1	38	(S)	28	(S)	25	
Hart	(4)		30	(S)	20	(S)	28	
Riviera	(4)		25	(S)	33	(S)	20 MS	(S)
Alexis	(5)	2	20	(S)	5 MR	(R)	0	(R)
Charm	(8)		23	(S)	8 MR	(MS)	Trace R	(R)
Cork			20	(S)	1	(S)	Trace	(R)
Simon			28	(S)	0.1	(R)	0.5 R	(R)
Triumph		3	13	(MS)	25	(S)	3 MR	(R)
Prisma	(6)		15	(S)	20	(S)	1 MR	(MR)
Chariot	(3)	4	13 R	(S)	20 R	(S)	15 Ms	(S)
Felicie	(5)		23 R	(S)	20 R	(S)	13 MS	(S)
Landlord	(6)	5	40 MR	(MR)	30 MR	(MS)	23 R	(MR)
Draught	(6)		35 MR	(S)	30 MR	(S)	30 MR	(S)
Tankard	(7)		20 R	(S)	28 R	(S)	14 R	(MR)
Derkado	(8)		15 R	(S)	18 R	(S)	7 R	(R)
Optic	(8)		15 MR	(S)	15 R	(S)	3 R	(R)
Delibes	(9)		5 R	(MR)	10 R	(MS)	Trace R	(R)
Cooper	(8)		2 MR	(MS)	1 R	(S)	3 R	(R)
Tyne	(6)		4 R	(S)	4 R	(S)	15 MR	(MR)
Vada			5 MR	(-)	5 MR	(-)	3 MR	(-)
Trinity				(S)		(S)		(MR)
Pitcher				(MS)		(S)		(MR)
Scarlett				(MS)		(R)		(-)
4220.D.31				(S)		(R)		(-)
Madras				(MS)		(R)		(-)
Toddy	(9)			(MR)		(MR)		(MR)
Livet	((7))			(MR)		(MR)		(-)
Spey				(MR)		(MR)		(-)
SW 8732				(S)		(S)		(-)
NS 91029.12				(S)		(MS)		(-)
Fractal				(R)		(S)		(-)

*Percentage - mean of 2 replicates. All adult plant reactions susceptible unless stated
R = resistant MR = mixed resistant MS = mixed susceptible
S = susceptible ( ) seedling reaction

Table 6. Seedling and adult plant reactions* of spring barley cultivars to isolates of *Puccinia hordei* under glasshouse conditions

Isolate / Cultivar (NIAB rating)		Group	BRS-96-5 Race octal 273 (BBV-1,2,4,5,6,8)		BRS-96-6 Race octal 1677 (BBV-1,2,3,4,5,6,8,9,10)	
Dandy	(4)	1	4	(3)	4	(3)
Hart	(4)		3	(3)	3	(3)
Riviera (4)			3	(3)	3	(3)
Midas			4	(3)	4	(3)
Alexis	(5)	2	Oi,3	(Oi,3)	3	(3)
Charm	(8)		Oi,3	(Oi,3)	3	(3)
Cork			Oi,3	(Oi,3)	3	(3)
Simon			Oi,3	(Oi,3)	3	(3)
4220.D.31			Oi,3	(Oi)	3	(3)
Scarlett			2,3	(Oi,3)	3	(3,2)
Madras			Oi,3	(Oi,3)	3,2	(3)
Triumph		3	Oi,3	(On,3)	3	(3)
Prisma	(6)		2,3	(2,3)	3	(3)
Chariot	(3)	4	3,2	(3)	3,2	(3)
Felicie	(5)		3,2	(3)	3,2	(3)
SW 8732			3,2	(3,2)	3	(3)
Landlord†	(6)	5	2,3	(2^+)	2,3	(2^+)
Draught†	(6)		2,3	(3)	2,3	(3)
Tankard†	(7)		2,3	(1,2,3)	3,2	(3,2)
Trinity†			2,3	(3)	2,3	(3)
Pitcher†			2,3	(3)	2,3	(3)
NS 91029.12			2,3	(3,2)	2,3	(3,2)
Tyne	(6)		2,3	(2,3)	2,3	(3,2)
Vada			2,3	(-)	2,3	(-)
Optic	(8)		2,3	(On,1,2,3)	3,2	(3,2)
Toddy†	(9)		2,3	(1,2)	2,3	(3,2)
Cooper	(8)		1,2,3	(1,2)	2,3	(2,3)
Spey			1,2,3	(Oi,3)	2,3	(2,3)
Fractal			1,2,3	(Oc,2,3)	2,3	(2)
Heron			2	(-)	2,3	(-)
Delibes	(9)		Oi,2	(Oi,2,3)	2,3	(2,3)
Derkado	(8)		1,2	(Oc,2)	2,3	(3,2)
Livet	((7))		Oi,2	(On,1,2)	2	(2,3)

*0-2 type reaction - resistant
3-4 type reaction - susceptible
Where more than one reaction type is expressed by a single cultivar, classification is based on the prevalent response
Seedlings assessed on 1st leaf Adult plants assessed on flag leaf
† - derivatives of cv. Chariot

RHYNCHOSPORIUM OF BARLEY

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Several of the current NIAB recommended winter barleys carry a race-specific resistance (BRR-2). Others carry adult plant resistance effective against the virulence(s) carried by some isolates. The majority of the NIAB fully recommended spring barley cultivars are highly susceptible to *Rhynchosporium*. Digger, which has shown high levels of resistance over a number of years, was heavily infected by an isolate which had shown increased virulence to it in 1995 seedling tests. This race-specific resistance also appears to be carried by cv. Livet.

SEEDLING TESTS WITH 1996 ISOLATES

Leaf samples of *Rhynchosporium secalis* were received from 29 winter and 4 spring barley cultivars in 1996. The geographic origins of the samples are given in Table 1.

Table 1. Geographic origin of *Rhynchosporium* samples received in 1996

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

Isolates were successfully cultured from twenty-eight of the samples and tested on a set of differential cultivars. Test cultivars and their resistance factors are given in Table 2.

Results

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

Table 2. Differential test cultivars for *Rhynchosporium secalis*

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

Table 3. Virulence factor combinations identified from the 1996 isolates

No. of isolates	Differential cultivars in linear order							Race octal
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
1	0	0	0	0	1	0	0	4
3	0	0	0	1	1	0	0	14
1	1	0	0	1	1	0	0	114
2	1	0	0	0	1	0	0	104
2	1	0	1	1	1	0	0	134
1	0	0	0	0	1	1	1	7
3	1	0	0	0	1	1	1	107
6	1	0	0	1	1	1	1	117
1	0	0	1	1	1	1	1	37
3	1	0	1	1	1	1	1	137
1	0	1	1	1	1	1	1	77
2	1	1	1	1	1	1	1	177
1	0	1	1	0	1	0	0	64
1	0	1	1	1	0	0	0	74

1 = susceptible 0 = resistant

The virulence combinations gave a range from single virulence factors in 2 isolates to the widely virulent race octal 177, also found in 2 isolates, which carries virulence to all the differential cultivars. Virulence to cv. La Mesita (BRR-5) was detected in 11 isolates in 7 different combinations. Two of these isolates were sampled from crops of cv. Pipkin (BBR-5). Five of the La Mesita virulent isolates also carry virulence to cv. Osiris (BRR-6) and as in previous years BRV-6 was found only in combination with BRV-5.

Virulence to cv. Digger, found in some isolates from the 1994 and 1995 surveys, was not detected in the 1996 isolates.

Table 4. Frequencies of individual virulences, 1988-1995

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

Frequencies of virulences (Table 4) to cvs Armelle (BRR-1), Astrix (BRR-2) and Pirate (BRR-7), which were at a reduced level in 1995, showed an increase in 1996. The increase in frequency to BRR-1 and BRR-2, a trend first noted in 1992, is probably attributable to several of the current winter barley cultivars carrying these resistances (Table 5). The decline in the frequency of these virulences in 1995 was probably due to unrepresentative sampling combined with a low number of isolates tested.

GLASSHOUSE TESTS WITH SPECIFIC ISOLATES OF *RHYNCHOSPORIUM*

Adult Plant Tests

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

Race octal	BRV
117	1,2,3,4,7
74	3,4,5,6
0	0

The plants were inoculated by spraying with a fresh spore suspension, placed in dew chambers at 15°C for 48 h post-inoculation and then incubated in the glasshouse at approximately 15°C for 16 days. Assessments were made of the area of flag leaves infected and cultivars were classified on a 0-9 scale as being resistant (0-4) or susceptible (5-9).

Seedling tests

Seedlings of the cultivars, grown to the second leaf stage, were inoculated with the same isolates and incubated under the same conditions as the adult plants. Seedlings were assessed on infection levels on the second leaf and classified on the same 0-9 scale.

Results

Seedling and adult plant test results are given in Table 5 (winters) and Table 6 (springs). Cultivars are grouped within the tables primarily on the basis of similarities in the patterns of their adult plant responses to the isolates.

Winter barleys

Group 1: Cultivars were generally susceptible to the isolates although seedlings of some of the cultivars were resistant to Race octal 0. Cultivar Linnet, not included in these adult plant tests, was susceptible to all the isolates in seedling tests but had expressed adult plant resistance in 1995 tests to isolates not carrying virulence factor BRV-1 and BRV-2, suggesting it may have adult plant resistance effective against isolates not carrying these virulence factors.

Group 2: Within this Group, cultivars were susceptible to Race octal 117 only. Cultivar Sprite was adult plant resistant although it was susceptible at the same growth stage to an isolate carrying the same virulence factors in 1995 tests. Cultivar Intro had also been susceptible to the same isolate in 1995 but was only included in seedling tests in 1996 as were cvs Baton and Spirit.

Group 3: The adult plant responses of these cultivars to the isolates suggest they should be placed within Group 2 but their susceptible seedling reactions to Race octal 74 differentiated them.

Group 4: As with Group 3 cultivars, the adult plant responses of cvs Athene (BRR-3), Epic and Muscat suggest that they should also be in Group 2, although they are more heavily infected by Race octal 0. They differ from Group 2 cultivars, however, in being susceptible as seedlings to Race octal 74. Other cultivars within this Group were tested as seedlings only, where they showed a similar pattern of responses to the isolates.

Group 5: Cultivar Pipkin was susceptible to the isolate Race octal 74 which carries the corresponding virulence factor (BRV-5). None of the cultivars included in the tests appeared to carry this resistance.

Group 6: The adult plant resistance of cv. Manitou was effective against all three isolates.

Spring barleys

Group 1: The majority of the currently recommended spring barley cultivars were susceptible. A few cultivars, Trinity, Toddy and Fractal, not included in adult plant tests, were classified as resistant to Race octal 0 in seedling tests.

Group 2: The race-specific resistance of cv. Armelle (BRR-1) was confirmed by the isolates.

Group 3: Cultivar La Mesita (BRR-5) was susceptible as a seedling to isolate Race octal 74, the only isolate in these tests carrying the corresponding virulence BRV-5. This cultivar was not included in 1996 adult plant tests but previous years' data show it to be susceptible as an adult plant to isolates not carrying virulence factor BRV-5.

Group 4: The race-specific resistance of cv. Osiris (BRR-6) was overcome in seedling tests by isolate Race octal 74. Virulence to this cultivar has remained at a low frequency in the pathogen population.

Group 5: A few isolates cultured from samples received in the 1994 and 1995 surveys induced higher infection levels (up to 10%) on cv. Digger than had been seen previously. The isolate designated Race octal 0 in these tests was sub-cultured from one of the Digger-virulent isolates. This virulence was confirmed with cv. Digger being heavily infected in the adult plant (rating of 9) and seedling (rating of 8) tests. Cultivar Livet which was not tested as an adult plant was also susceptible only to Race octal 0 as a seedling.

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

Cultivar (NIAB rating)		Group	Race octal 117 BRV-1,2,3,4,7		Race octal 74 BRV-3,4,5,6		Race octal 0 BRV-0	
Prelude		1	8	(5)	8	(8)	8	(5)
Gaelic	(5)		8	(6)	7	(8)	6	(6)
Pastoral	(7)		7	(9)	7	(8)	6	(8)
Spice	(8)		7	(7)	8	(7)	8	(3)
Fighter	(6)		7	(9)	8	(8)	8	(8)
Portrait			5	(8)	7	(8)	7	(4)
Rifle	(6)		6	(8)	7	(5)	6	(0)
Falcon				(8)		(7)		(5)
Linnet	(6)			(9)		(8)		(8)
Angora	(7)	2	8	(9)	0	(0)	0	(1)
Melanie	(8)		8	(9)	0	(1)	0	(0)
Sunrise	(7)		8	(8)	0	(0)	0	(2)
Halcyon	(5)		7	(8)	0	(0)	0	(1)
Gleam	(7)		6	(8)	0	(0)	0	(0)
Astrix	BRR-2		6	(9)	0	(0)	0	(1)
Regina	(7)		5	(9)	0	(0)	2	(4)
Sprite	(7)		0	(7)	0	(0)	0	(0)
Baton	(7)			(7)		(0)		(0)
Spirit	(8)			(7)		(0)		(0)
Intro	(5)			(8)		(0)		(1)
Tokyo		3	5	(7)	1	(7)	0	(7)
Fanfare	(8)		8	(8)	1	(8)	3	(8)
Athene	BRR-3	4	8	(8)	0	(6)	4	(0)
Epic	(5)		8	(7)	0	(7)	4	(2)
Muscat	(7)		7	(8)	0	(6)	4	(3)
Jewel	(8)			(7)		(9)		(1)
Igri	BRR-4		1	(9)		(6)		(2)
Pirate	BRR-7			(8)		(4)		(0)
Hanna	(8)			(8)		(4)		(4)
Vertige	(5)			(8)		(3)		(2)
Peridot	(5)			(6)		(4)		(3)
Pipkin	(3)	5	0	(0)	8	(9)	0	(0)
Manitou	(8)	6	0	(1)	0	(7)	0	(5)

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

Resistant: 0-4, Susceptible: 5-9

( ) seedling reaction

Table 6. *Reactions of spring barley cultivars (adult plants and seedling) to specific isolates of *Rhynchosporium secalis* in glasshouse tests

Cultivar (NIAB rating)		Group	Race octal 117 BRV-1,2,3,4,7		Race octal 74 BRV-3,4,5,6		Race octal 0 BRV-0	
Alexis	(4)	1	9	(8)	9	(9)	9	(9)
Chariot	(3)		9	(7)	9	(9)	9	(8)
Optic	(4)		9	(8)	9	(9)	9	(8)
Cork	(6)		9	(7)	9	(9)	9	(7)
Felicie	(7)		9	(8)	9	(9)	9	(8)
Delibes	(7)		9	(9)	9	(9)	9	(8)
Prisma	(7)		9	(8)	9	(9)	9	(9)
Tankard	(3)		9	(9)	9	(9)	9	(9)
Charm	(5)		9	(8)	9	(9)	9	(8)
Hart	(5)		9	(9)	9	(9)	9	(7)
Cooper	(6)		9	(9)	8	(9)	9	(8)
Riviera	(5)		9	(8)	9	(9)	9	(8)
Derkado	(3)		8	(8)	8	(9)	9	(8)
Dandy	(7)		8	(7)	8	(8)	7	(5)
Tyne	(6)		7	(7)	6	(9)	7	(8)
Landlord	(7)		6	(7)	6	(9)	9	(5)
Draught	(7)		6	(6)		(8)	8	(7)
Madras				(8)		(7)		(5)
Pitcher				(8)		(5)		(5)
Scarlett				(8)		(9)		(5)
Trinity				(7)		(8)		(4)
Toddy	(4)			(8)		(7)		(2)
Fractal				(8)		(8)		(4)
Spey				(9)		(5)		(5)
Armelle	(BRR-1)	2	6	(9)	0	(0)	0	(1)
La Mesita	(BRR-5)	3		(0)		(9)		(0)
Osiris	(BRR-6)	4		(0)		(6)		(0)
Digger		5	0	(0)	2	(2)	9	(8)
Livet	(8)			(0)		(0)		(6)

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

Resistant: 0-4, Susceptible: 5-9

( ) seedling reaction

NET BLOTCH OF BARLEY

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The large number of samples received reflects reports of the high incidence of net blotch in 1996. Although isolates were identified carrying single virulence factors the majority of the isolates carried virulence to a large number of the differential cultivars which was reflected by the frequencies of virulence to the cultivars being at their highest levels for several years. The majority of the currently recommended winter barleys were susceptible in adult plant tests whereas the majority of the spring barley cultivars were classified as resistant.

GLASSHOUSE SEEDLING TESTS WITH 1996 ISOLATES

One hundred and three samples of net blotch were received, of which 92 were from a range of winter barley cultivars with the remainder coming from spring barleys. The geographic origins are given in Table 1.

Table 1. Geographic origins of net blotch samples received in 1996.

Location (MAFF Region)	Number of samples
South East	11
East Anglia	13
East Midlands	8
West Midlands	38
South West	5
North West	1
North	16
Yorkshire and Humberside	10
Wales	1

Eighty-five isolates were successfully tested on a set of 13 differential cultivars.

Results

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

Table 2. Virulence frequencies (%) corresponding to each differential cultivar (UK CPV Surveys 1991-1996).

Code Number	Cultivar	1991	1992	1993	1994	1995	1996
1	C.I.5401	0	0	0	0	0	9
2	C.I.6311	13	2	0	14	13	21
3	C.I.9820	0	0	0	3	6	9
4	C.I.739	31	13	0	14	38	51
5	C.I.1243	13	9	0	23	13	48
6	C.I.4795	13	4	0	6	9	35
7	C.I.4502	19	4	0	11	0	21
8	C.I.4979	38	4	0	29	44	34
9	Proctor	56	52	43	97	88	92
10	Code 65(W)	31	9	100	3	16	35
11	C.I.9518(W)	88	56	29	100	100	95
12	Tenn.61-119(W)	75	50	0	69	50	88
13	C.I.9214	19	4	0	3	9	32
No. of isolates tested		15	46	7	35	32	85

W = winter cv.

Virulences were generally at a higher frequency to all the cultivars than those seen since 1988. Virulence to cv. CI 5401, last detected in 1989, was found in 8 isolates as was virulence to cv. CI 9820 which has been at a low frequency in the pathogen population in recent years. Six of the isolates combined virulences to cvs CI 5401 and CI 9820 supporting the postulation that some of the differential cultivars either carry a common resistance factor(s) or that the specific virulences are associated in the pathogen (Jones, Maeda and Clifford, 1989).

The virulences identified occurred in 50 varying combinations in the different isolates. The virulence combinations which are based on the differential code numbers (Table 2) gave a range from differing single virulence factors in four isolates to one isolate carrying virulence to all of the differential cultivars.

The identification of isolates carrying a wider range of virulences than seen in recent seasons has not surprisingly coincided with reports of the highest incidence of net blotch in the UK for a number of years. This is supported by the high number of survey samples received.

GLASSHOUSE TESTS WITH A SPECIFIC ISOLATE OF NET BLOTCH

Adult Plant Tests:

Spring and winter barleys were grown in the glasshouse until full emergence of the flag leaf. Two replicates of each cultivar were inoculated with a spore suspension prepared as previously described (Jones and Clifford, 1996). The virulence factors carried by the isolate were :

BNV-	Origin
4,8,9,11,12,13	cv. Intro, Norfolk

Following inoculation, the plants were placed in dew chambers in the dark at 15°C for 24 h post-inoculation and then incubated in the glasshouse at approximately 15°C for 12 days.

Assessments were made of the area of flag leaves infected and cultivars were classified on a 0-9 scale as being resistant (0-4) or susceptible (5-9).

Seedlings:

Seedlings of the cultivars grown to the second leaf stage were inoculated with the same isolate under identical conditions to the adult plants. Seedling x isolate interactions were classified on a 0-4 scale (Clifford and Jones, 1981) as resistant (0-2) or susceptible (3-4). Symptoms on the adult plants were mainly of a striping type although some spring cultivars gave netting symptoms.

Results

Winter barleys: The majority of the cultivars were susceptible. Cultivars Hanna, Prelude, Tokyo, Pipkin and Regina were classified as resistant although the former three were susceptible in 1995 glasshouse tests to an isolate differing only from isolate BNS-96-45 in that it lacked virulence to the differential cv. CI 9214 (Jones and Clifford, 1996). Only cvs Tokyo and Peridot expressed resistance in seedling tests.

Spring barleys: The spring cultivars (Table 4) as in previous years' tests, displayed a greater range of quantitative responses than the winter barleys to the isolates against which they were tested. Cultivar rankings generally confirmed those of 1995 tests with an isolate carrying virulence factors 4,7,9,11 and 12 (Jones and Clifford, 1996). The resistant cultivars also expressed that resistance at the adult plant stage with only cvs Fractal and Pitcher being classified as resistant in seedling tests.

Cultivars Felicie, Hart and Draught were highly resistant with cvs Felicie and Hart being the only ones, together with cv. Riviera, to express netting type symptoms in adult plant tests. Of the differential cultivars, CI 4979, CI 739 and CI 9214 carried resistance which was effective against this isolate at the later growth stages only.

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

Isolate		BNS-96-45 (BNV-4,8,9,11,12,13)	
Cultivar (NIAB Rating)		*Adult plant reaction	†Seedling reaction
Portrait		8	4
Puffin	(4)	8	4
Melanie	(5)	8	4
Falcon		8	4
Manitou	(4)	8	3
Gaelic	(8)	8	4
Sunrise	(5)	8	4
Angora	(5)	8	3
Pastoral	(8)	8	4
Linnet	(7)	8	3
Sprite	(8)	8	4
Spice	(7)	8	4
Epic	(8)	7	3
Muscat	(7)	7	3
Fighter	(7)	7	3
Rifle	(8)	7	3
Fanfare	(8)	7	3
CI 9518		8	4
Tenn.61-119		7	3
Code 65		6	3
Gleam	(5)	6	4
Intro	(8)	5	3
Halcyon	(7)	5	3
Hanna	(7)	4	3
Pipkin	(8)	3	4
Prelude		3	4
Regina	(8)	2	3
Tokyo		1	2
Baton	(7)	-	4
Spirit	(6)	-	4
Vertige	(9)	-	4
Jewel	(6)	-	3
Peridot	(6)	-	2

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

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

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

Isolate	BNS-96-45 (BNV-4,8,9,11,12,13)		
Cultivar	*Adult plant reaction		†Seedling reaction
Alexis	9		4
Cooper	8		4
Cork	5		4
Optic	5		3
Charm	5		3
Landlord	4		4
Prisma	4		4
Riviera	4	(N)	3
Tyne	4		3
Tankard	4		3
Dandy	3		3
Derkado	2		4
Delibes	2		4
Chariot	2		3
Felicie	1	(N)	3
Hart	1	(N)	3
Draught	0		3
Pitcher	-		2
Fractal	-		2
Scarlett	-		3
Madras	-		3
Spey	-		3
Livet	-		3
Toddy	-		4
Trinity	-		4
CI 5401	0		1
CI 6311	0		2
CI 9820	0		1
CI 739	2		3
CI 1243	2		2
CI 4795	2		2
CI 4502	3		2
CI 4979	2		3
Proctor	6		3
CI 9214	2		3

* area of flag leaf area infected on a 0-9 scale (mean of 2 plants)
Resistant: 0-4, Susceptible: 5-9
† seedling assessed on reaction type on a 0-4 scale
Resistant: 0-2, Susceptible: 3-4
(N) = netting type symptoms

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

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Of 178 infected samples received in 1996, 46% contained barley yellow mosaic virus (BaYMV) and 67% barley mild mosaic virus (BaMMV). Puffin, Halcyon and Fighter were the cultivars with the largest numbers of samples. BaMMV predominates on Puffin and Halcyon, often producing very pronounced symptoms. One new outbreak of resistance-breaking BaYMV was reported. Virus (BaMMV) was reported for the first time in the Lothian Region of Scotland.

INTRODUCTION

The survey, begun in 1987, aims to determine the distribution and relative frequency of the two mosaic viruses (barley mild mosaic virus: BaMMV; barley yellow mosaic virus: BaYMV) on winter barley, to detect regional or cultivar differences and to monitor the development of resistance-breaking strains. The viruses are soil-borne, being transmitted by the root infecting fungus *Polymyxa graminis*, and persist in soil for many years. A single (recessive) gene (*ym4*) confers immunity to the common isolates of both viruses in a number of European cultivars but, since 1988, resistance-breaking isolates of BaYMV ("BaYMV-2") have been detected in the UK and other parts of Europe. Several strains of BaYMV with different specific virulences have been reported in Japan. New cultivars with resistance genes from East Asian barleys are being developed for the European market and a knowledge of the variation in these viruses and of their interaction with barley genotypes is therefore likely to become increasingly important.

METHODS

Plants with symptoms were received from farmers as a result of publicity by the Arable Research Centres and NIAB and some also came via MAFF CSL Harpenden Laboratory. Leaves were tested by enzyme-linked immunosorbent assay (ELISA) for the presence of both viruses as described by Adams (1990).

RESULTS AND DISCUSSION

178 positive samples were received in 1996, considerably more than in the last three years and the second largest annual number in the ten years of the survey (Fig. 1). This was probably a consequence of three factors which favour the disease:

(a) a mild autumn, which favours root infection by the fungus vector

(b) a cold winter, which stimulates virus movement from roots to leaves and

(c) a relatively long and cool spring, prolonging symptom expression.

Most samples (67%) contained BaMMV and 46% had BaYMV (Table 1). For the 113 samples of which the cultivar is known, 34 were of Puffin and 17 were of Halcyon, on which (as for the other malting cultivars) BaMMV has been predominant in previous years. Symptoms on these cultivars are also often very pronounced with chocolate-brown necrotic flecks in addition to the typical pale yellow mosaic symptoms. One new outbreak of resistance-breaking BaYMV was reported. As in previous years, most samples were from Eastern England and the Cotswold/Wiltshire regions, but BaMMV was reported for the first time from Cornwall (where only BaYMV had previously been known) and from the Lothian Region of Scotland (from which neither virus had previously been reported).

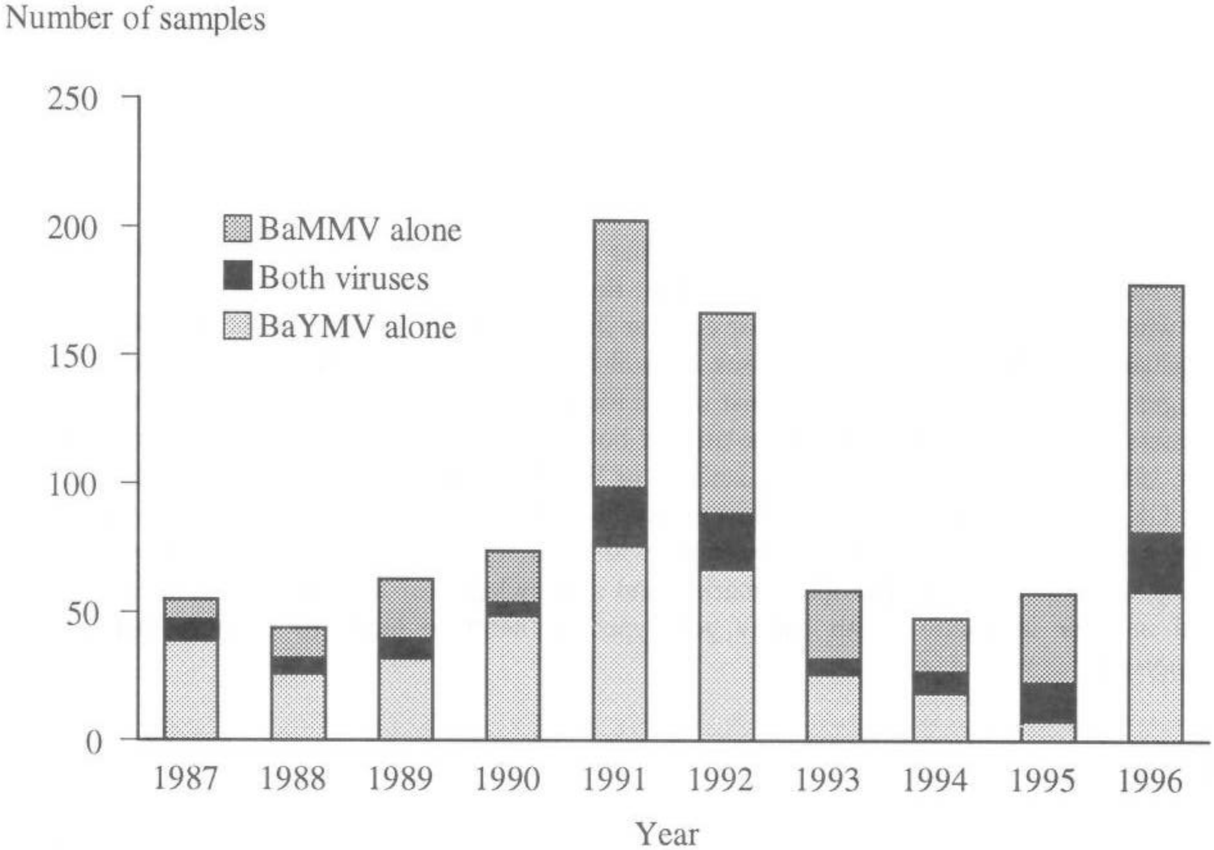

Fig. 1. Number of mosaic virus samples received during each year of the survey

REFERENCE

ADAMS M.J. (1990). The distribution of barley yellow mosaic virus (BaYMV) and barley mild mosaic virus (BaMMV) in UK winter barley samples, 1987-1990. *Plant Pathology* **40**, 53-58.

Table 1. Mosaic virus samples from 1996, classified by cultivar

Cultivar	BaMMV alone	BaYMV alone	Both	Total Samples
Fanfare	1	0	0	1
Halcyon	16	0	1	17
Maris Otter	0	1	0	1
Melanie	1	0	0	1
Pipkin	2	0	0	2
Puffin	27	3	4	34
Malting	47	4	5	56
Angora	0	2	0	2
Bronze	0	1	0	1
Fighter	5	7	5	17
Gaelic	1	2	0	3
Hanna	0	2	0	2
Intro	0	2	0	2
Lagune	1	0	0	1
Linnet	0	3	0	3
Manitou	3	4	3	10
Mixture	0	3	0	3
Pastoral	1	6	3	10
Plaisant	0	1	0	1
Princess	1	0	0	1
Target^{R}	0	1	0	1
Feeding	12	34	11	57
Unknown	37	21	7	65
Total	96	59	23	178

^{R} indicates resistant (*ym4*) cultivar

MILDEW OF OATS

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Race 5 (OMV 1,2,3) was identified in 80% of the 66 isolates tested with the remainder combining these virulence factors with OMV-4 (Race 7). Isolates carrying virulence to OMR-4 (derived from *Avena barbata*) were last detected in 1993.

SEEDLING TESTS WITH 1996 ISOLATES

Sixty-seven samples of oat mildew received from a range of winter (25) and spring (42) oat cultivars. Sixty-three these came from 3 trial sites (Table 1). Isolates of *Erysiphe graminis avenae* were cultured from 66 of the leaf samples and tested on a set of differential cultivars (Table 2), virulence to all of which has been identified previously.

Table 1. Geographic origins of oat mildew samples received in 1996

Location (MAFF Region)	Number of samples
North	
Cockle Park, Northumberland	25
Yorkshire and Humberside	
Headley Hall, Leeds	13
West Midlands	
Newport, Shropshire	25
East Anglia	
Cambridge	1
Scotland	
Edinburgh	1
Aberdeen	1
Dundee	1

Table 2. Differential cultivars used for isolate testing

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

Results

Isolates were identified as carrying one of two virulence combinations. Race 5 (OMV-1,2,3), a relatively complex race which has been at a high frequency in the pathogen population in recent years (Table 3) was identified in 53 (80%) of the isolates. The other race identified from the 1996 isolates was race 7 (OMV-1,2,3,4). This widely virulent race carries virulence to the differential cv. Cc 6490 which derives its resistance from *Avena barbata* (OMR-4). Virulence to this resistance was not detected in the 1994 and 1995 samples but prior to this had shown a fluctuating frequency in survey tests (Table 3). Isolates identified as carrying OMR-4 were cultured from leaf samples received from two sites: Cockle Park, Northumberland and Newport, Shropshire.

Table 3. Virulence combination (race) frequencies identified from samples received 1986/96

Virulence		**Frequency (% total)**										
Group	Race	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
OMV 1	2	0	0	0	0	0	0	0	0	0	0	0
OMV 1,2	3	31	15	32	0	0	3	0	0	0	0	0
OMV 1,3	4	0	0	0	0	0	0	0	0	0	0	0
OMV 1,2,3	5	63	85	68	85	66	19	83	80	100	100	80
OMV 1,2,4	6	0	0	0	0	7	5	0	0	0	0	0
OMV 1,2,3,4	7	6	0	0	15	27	73	17	20	0	0	20
No. of isolates tested		16	21	34	26	15	37	42	35	32	14	66

CROWN RUST OF OATS

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SEEDLING TESTS WITH 1996 ISOLATES

Only four samples of oat crown rust, all from spring oat cultivars, were received in 1996. This is a much lower number than received in recent seasons: 1995 (24 samples), 1994 (26 samples) and 1993 (28 samples). Isolates of *Puccinia coronata avenae* were cultured from the samples and tested on the International set of 10 differential cultivars: Anthony, Victoria, Appler, Bond, Landhafer, Santa Fé, Ukraine, Trispernia, Bondvic and Saia. The currently NIAB recommended winter and spring oat cultivars were also included in the tests.

Two races were identified (Table 1). Race 272, last detected in 1990, was found in one isolate and carries virulence to the differential cultivars Appler, Ukraine and Saia. The other isolates were identified as race 289 which differs from race 272 only in lacking virulence to cv. Ukraine.

Table 1 Locations and cultivars from which crown rust samples were received in 1996 with race identified for each sample.

Location (MAFF Region)	Cultivar	Race
South West		
Newquay, Cornwall	Image	272
	Dula	289
	Breeding Line	289
Penzance, Cornwall	Unknown	289

Of the 1996 NIAB recommended winter and spring oat cultivars only the spring oat cv. Piper was classified as resistant. It expressed a mixed, mainly resistant reaction to the isolates.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1997

Variety diversification schemes to reduce the spread of mildew in spring barley and yellow rust in winter wheat have been produced by the UKCPVS Committee since 1975. In 1986, the barley scheme was expanded to include both winter and spring varieties. In 1988, spring wheat varieties were added to the wheat scheme. The schemes which follow update those in the last Annual Report.

The scheme for mildew of wheat was suspended in 1990, its usefulness having been severely restricted by the limited range of specific resistances in current varieties and the increasing complexity of the mildew population. However, the situation is under constant review and the mildew scheme will be reinstated when appropriate. Wheat varieties with good resistance to mildew are available and should be grown whenever possible.

The brown rust of wheat scheme has also been suspended for the present, due to the lack of suitable diversification available in current varieties. This situation will be reviewed each year.

Diversification schemes are used to encourage farmers to grow a number of varieties possessing different specific resistances, either in adjacent fields or in the same field as a variety mixture. Disease is unlikely to spread between varieties possessing different specific resistances because spores generated on one variety are largely non-virulent on the other.

The general principles and history of the UK diversification schemes have been described by Priestley and Bayles (1980). Evidence that the schemes are effective in reducing the spread of disease has been summarised by Priestley and Bayles (1982) and the use of cultivar mixtures as a method of disease control has been reviewed by Wolfe, Barrett and Jenkins (1981).

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WOLFE, M.S., BARRETT, J.A. & JENKINS, J.E.E. (1981). The use of cultivar mixtures for disease control. In *Strategies for the control of cereal diseases,* Ed J.F. Jenkyn & R.T. Plumb, 73-80. Blackwell Scientific Publications, Oxford.

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST IN WHEAT. 1997.

Severe infections may result if yellow rust spreads between varieties which are susceptible to the same races of the pathogen. This risk is reduced if varieties with good resistance are grown. The spread of disease can be further limited by growing different varieties in neighbouring fields, provided that the varieties are not susceptible to the same races of yellow rust. The Diversification Scheme should be used to choose varieties to grow adjacent to one another.

Choosing varieties to grow together

1. Select first-choice variety and locate its Diversification Group (DG).
2. Find this DG under 'Chosen DG' down the left hand side of the table.
3. Read across the table to find the risk of disease spread for each companion DG.
   + = low risk of spread of yellow rust
   Y = high risk of spread of yellow rust
   y = moderate risk of spread of yellow rust
4 Wherever possible choose combinations of varieties marked '+'. A combination marked 'y' is a lesser risk than one marked 'Y'.

DG1	DG2	DG9	DG0
(highly resistant)	*(WYR6,9)*	*(WYR17)*	*(no specific resistance)*
Buster	Beaver	Abbot	Soissons
Cadenza	Haven	Beaufort	Avans (S)
Caxton	Rialto	Brigadier	Baldus (S)
Charger		Equinox	Promessa (S)
Dynamo	**DG3**	Harrier	
Encore	*(WYR13)*	Hussar	
Hunter	Crofter	Lynx	
Mercia	Riband	Madrigal	
Axona (S)		Reaper	
Chablis (S)	**DG7**		
Imp (S)	*(WYR CV)*		(S) = spring wheat
Shiraz (S)	Consort		
	Hereward		
	Spark		

			Companion DG			
Chosen DG	1	2	3	7	9	**0**
1	+	+	+	+	+	+
2	+	**Y**	y	+	y	**Y**
3	+	y	**Y**	y	y	**Y**
7	+	+	y	**Y**	+	**Y**
9	+	y	y	+	**Y**	**Y**
0	+	**Y**	**Y**	**Y**	**Y**	**Y**

Note: Varieties in DG1 have good resistance to yellow rust spreading from any other variety and can therefore be used to diversify with varieties in any DG, including others in DG1. Varieties in DG0 are susceptible to yellow rust spreading from any variety and therefore do not contribute to diversification.

VARIETAL DIVERSIFICATION SCHEME TO REDUCE THE SPREAD OF MILDEW IN BARLEY 1997

Severe infection may result if mildew spreads between varieties which are susceptible to the same races of the pathogen. This risk is reduced if varieties with good resistance are grown. The spread of disease can be further limited by growing different varieties in neighbouring fields, provided that the varieties are not susceptible to the same races of mildew. The Diversification Scheme should be used to choose varieties to grow adjacent to one another.

Choosing varieties to grow together:

1. Select first-choice variety and locate its Diversification Group (DG).
2. Find this DG number under 'Chosen DG' down the left hand side of the table.
3. Read across the table to find the risk of spread of mildew for each companion DG:

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

DG1
Fighter (W)
Alexis (S)
Chariot (S)
Dandy (S)
Derkado (S)
Draught (S)
Felicie (S)
Hart (S)
Landlord (S)
Riviera (S)
Tankard (S)

DG4
Pipkin (W)
Tyne (S)

DG5
Falcon (W)
Rifle (W)
Spice (W)

DG7
Cooper (S)
Delibes (S)

DG8
Manitou (W)
Charm (S)

DG9
Optic (S)

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

DG0
Angora (W)
Fanfare (W)
Halcyon (W)
Hanna (W)
Intro (W)
Linnet (W)
Melanie (W)
Muscat (W)
Pastoral (W)
Portrait (W)
Puffin (W)

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

(W) Winter barley, (S) Spring barley

Companion DG

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

Note: Varieties in DG1 have good resistance to mildew spreading from any other variety and can be used to diversify with varieties in all other DGs, including DG1. DG0 varieties are susceptible to mildew spreading from any variety and do not contribute to diversification.