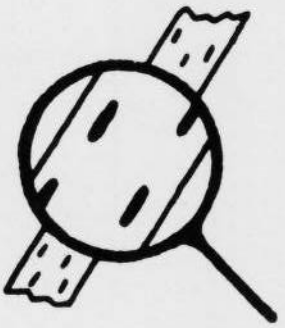
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1989 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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1989 Annual Report

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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 is the early detection of increased virulence compatible with those resistances currently 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 within the United Kingdom, who collect samples of infected leaves from field crops and cultivar trials and send them by post to the three testing centres:

- National Institute of Agricultural Botany, Cambridge, for yellow rust of wheat and barley (and from April 1990 mildew of wheat and mildew of barley).

- Institute of Plant Science Research, Cambridge, for mildew of wheat and barley (until April 1990).

- Institute for Grassland and Animal Production, 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 are also used including mobile nurseries and the wind impaction spore trap.

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 winter wheat and winter and spring barley cultivars in diversification groups on the basis of their specific resistances. The results of the virulence tests and the diversification schemes are published shortly afterwards in the Annual Report.

The information provided by the Survey is used in various ways. Isolates possessing new virulences are used by the National Institute of Agricultural Botany to evaluate the resistance of cereal cultivars in trial in England and Wales. These isolates are also used 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 in the National Institute of Agricultural Botany Farmers Leaflet No.8 'Recommended varieties of cereals', the Scottish Agricultural Colleges leaflet 'Recommended varieties of cereals', and by the Agricultural Development and Advisory Service.

CEREAL DISEASE CONTROL IN THE 1990s AND THE ROLE OF THE UK CEREAL PATHOGEN VIRULENCE SURVEY

A POLICY STATEMENT

There are two main methods available for the control of cereal disease, both of which are essential components of modern cereal husbandry. These are the use of genetic resistance, in the form of resistant varieties, and chemical control by fungicides. The UKCPVS considers that the recent emphasis placed on fungicide use has partly overshadowed the potential benefits of varietal resistance and that the two control methods are currently out of balance. We advocate the full and proper exploitation of genetically controlled host resistance to pathogens.

Despite being generally cost effective with current price structures, fungicides have a number of disadvantages, including the development of pathogen insensitivity, practical problems associated with application and environmental concerns. The only major drawback of genetic resistance is the possibility that it may be overcome by newly adapted pathogen races.

The UKCPVS provides a formal system of monitoring pathogen variation, which allows detection of new races at an early stage before they can cause widespread epidemics. The survey actively supports breeding for improved resistance and promotion of resistant varieties by releasing appropriate, up-to-date, pathogen isolates to breeders and variety testing authorities. The survey also makes possible the production of variety diversification schemes, which are used to reduce the risk of disease spread.

Unfortunately, the current range of cereal varieties has a dangerously narrow genetic base for resistance to an increasingly virulent spectrum of pathogen races, for example in wheat yellow rust and barley mildew. At the same time, there is an increasing incidence of pathogen resistance to the most important groups of cereal fungicides. In this situation, it is vital that the search for more diverse and durable forms of resistance should continue, supported by constant monitoring of pathogen variation by the UKCPVS.

EXPLANATION OF TERMS USED TO DESCRIBE RESISTANCE AND VIRULENCE IN THIS REPORT

Specific resistances and specific virulences

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 resistances are classified as R0 and isolates lacking specific virulences are classified as V0.

Specific resistances and virulences relating to particular cereal diseases are described by additional prefixes for crop (W = wheat, B = barley and 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 1989

Mildew of wheat

Virulence corresponding to the five most widely-used wheat mildew resistances, WMR 2, 4b, 6, 7 and 8, were all found at high frequencies in 1989. The four most common races of wheat mildew all carried WMV 2, 6 and 7. Pm3b may be a useful source of resistance. Isolates with a high level of resistance to triadimenol were common in 1989.

Yellow rust of wheat

The frequency of isolates with virulence for Slejpner (ie possessing WYV 9) rose to almost 100% during the 1989 epidemic. The combined virulence WYV 6,9 which confers virulence for Hornet, is now common and widespread throughout the UK. The susceptibility of Hornet to WYV 6,9 isolates was confirmed in adult plant tests, which also revealed that the new varieties Haven and Beaver are susceptible to isolates of this type.

Brown rust of wheat

Adult plant field tests together with seedling test results enabled the resistances present in wheat varieties to be classified. The winter wheat varieties Fortress and Apollo carry WBR 1. Two-thirds of the isolates tested were virulent on WBR 1 varieties but adult plant tests indicate that Hornet, Beaver, Slejpner and Dean carry additional adult plant resistance. The resistance of the winter wheat varieties Apostle, Pastiche, Gambit and Rendezvous was also effective at the adult plant stage as was that of the Spring wheat Axona.

Mildew of barley

The mlo resistance gene (BMR 9) remained effective during 1989, while BMR 3, 8 and 10 provided moderate resistance. All of the most frequent races of barley mildew were complex, with virulence corresponding to several BMR groups. Several resistances, not previously used by British barley breeders, may be effective in controlling mildew, notably Mlp. The sensitivity of barley mildew to the fungicides ethirimol, fenpropimorph and triadimenol continued to decline.

In N Ireland the level of BMV 4,9 like that of the other complex virulences, dropped back to levels of the year before, while levels of single gene virulences remained almost identical. Baytan seed-treatment appeared much less effective than in the previous two seasons.

Yellow rust of barley

All four samples received possessed the virulences BYV 1 and BYV 2. Three of these were also virulent on Triumph (BYR 3).

Brown rust of barley

The high incidence of barley brown rust in 1989 was reflected in the large number of leaf samples received. Although the widely virulent race octal 1673 was predominant, virulence to Triumph (BBR 10) was at a lower frequency than in recent years. Adult plant field tests suggest that the spring barley Alexis carries BBR 3.

Rhynchosporium of barley

Two new virulence combinations were identified from the 1989 isolates of Rhynchosporium. One of them combines virulence to resistance factors carried by Pipkin and Pirate and an increase in such races is of potential agricultural significance. The spring barley Digger was again resistant to all isolates both in seedling and adult plant tests.

Net blotch of Barley

Two isolates from Denmark were identified as carrying virulence factors commonly found in the UK pathogen population. One of the UK isolates was a 'spotting' strain, a form that occurs commonly in Denmark. In field nursery tests some common winter varieties were highly susceptible whereas others were resistant.

Fungally-transmitted mosaic viruses of barley

Barley yellow mosaic (BaYMV) was generally more frequent than barley mild mosaic, except on malting varieties. Two samples of BaYMV were received from varieties previously regarded as resistant and there is concern that such isolates may spread.

Mildew of oats

Race 5 (OMV 1,2,3) was predominant as in recent years. The widely virulent race 7 (OMV 1,2,3,4) was isolated from leaf samples of winter oats varieties grown in a breeding nursery at WPBS. This virulence combination is capable of attacking all current commercial varieties as well as overcoming the resistance derived from Avena barbata (OMR 4) currently used in breeding.

Crown rust of oats

Race 236, compatible with the differentials Anthony, Applers and Saia, was detected for the first time. A second isolate was identified as race 272 previously found in the UK pathogen population in 1974. Neither isolate contains previously undetected virulences.

MILDEW OF WHEAT

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The virulences corresponding to each of the five mildew resistance genes most widely used in British winter wheat varieties were all detected at high frequencies in 1989. All five virulences were carried by 24% of the isolates tested. *Pm3b* is a possible source of resistance to mildew. 31% of the isolates tested had a high level of resistance to triadimenol.

INTRODUCTION

In the 1988 survey of wheat powdery mildew, high levels of virulence, corresponding to each of the resistance genes most widely used in British wheat varieties (WMR 2, 4b, 6, 7 and 8; i.e. genes *Pm2*, *Pm4b*, *Pm6*, *Pm8* and *Mli*), were detected (Slater *et al.* 1989) (WMR = wheat mildew resistance factor; WMV = wheat mildew virulence factor). In addition to monitoring the frequency of each of these virulences, we investigated the potential effectiveness of several less widely-used resistances in the 1989 survey, by studying the frequencies of the corresponding virulences. The frequencies of common races of wheat mildew were also studied, in order to predict the value of diversification schemes for the control of wheat mildew, or of combining different resistance genes in new varieties.

MATERIALS AND METHODS

Two types of sample were collected. (i) A total of 70 single colony isolates were collected from infected leaves sent by UKCPVS participants (i.e. leaf isolates). Samples were received from Cockle Park, Northumberland (19 isolates), Owstwick, Humberside (5 isolates), Morley, Norfolk (42 isolates) and Barnet, Greater London (4 isolates). The source varieties were Focus (1 isolate), Norman (10 isolates) and President (4 isolates; all WMR2), Rendezvous (WMR2,4b,6; 3 isolates), Dean (2 isolates), Hornet (5 isolates;

Table 1. Differential varieties used in the survey of wheat mildew isolates in 1989. Avirulent infection type was 0, occasionally 1, and virulent IT was 4, occasionally 3, in all cases.

WMV group	Resistance gene(s)	Variety	WMV group	Resistance gene(s)	Variety
0		Cerco	2,6	*Pm2,Pm6*	Brimstone
1	*Pm1*	Anfield	2,7	*Pm2,Pm8*	Hornet
2	*Pm2*	Galahad	7,x	*Pm8,?*	Slejpner
4a	*Pm4a*	Khapli	4b,8	*Pm4b,Mli*	Mission
4b	*Pm4b*	Armada	5,8,?	*Pm5,Mli,?*	Tonic, Broom
5	*Pm5*	Hope	2,Talent	*Pm2,?*	Brock
6	*Pm6*	Timgalen	Axona		Axona
7	*Pm8*	Ambassador	Sona		Wembley
8	*Mli*	Mercia		*Pm7*	Transec
9	*Mld*	Maris Dove			

both WMR2,7), Slejpner (WMR7,x; 10 isolates), Apollo (WMR7,y; 2 isolates), Haven (WMR7,z; 5 isolates), Mercia (4 isolates) and Urban (3 isolates; all WMR8), Fortress (5 isolates; unknown resistance), and Cebeco 903 (4 isolates), Escorial (7 isolates) and ST120/84 (5 isolates), on which seedling resistance tests have not yet been carried out. (ii) A random sample of 63 single colonies was taken from seedlings of Cerco exposed on the roof of a tall building in the centre of Cambridge at the end of March 1989, at least 2 km from the nearest field of wheat (i.e. roof isolates).

Leaf isolates were tested for virulence or avirulence on detached first leaves of each of the varieties listed in Table 1. The presence or absence of a virulence was determined from the infection type of the isolate of mildew (Moseman *et al.* 1965). Roof isolates were tested on a similar set, except that Avalon was used instead of Galahad and Aquila instead of Mercia. The roof isolates were not tested on Brimstone, Hornet, Mission, Broom or Tonic, but were tested, in addition, on Asosan (WMR3a, *Pm3a*) and Chul (WMR3b, *Pm3b*).

Roof isolates were also tested for their response to triadimenol, formulated as Baytan and applied as a powder seed dressing at 0.07, 0.12, 0.19, 0.32, 0.54, 0.9, 1.5 and 2.5 g per kg seed of Cerco (the recommended field rate is 1.5 g/kg).

RESULTS AND DISCUSSION

Frequencies of virulences

Frequencies of virulences among leaf and roof isolates are given in Table 2. Generally, there was good agreement between virulence frequencies in the two samples, except that the frequency of WMV9 was 13% in the leaf isolates and 72% in the roof isolates ($\chi^2 = 46.9$). We have no explanation for this wide

Table 2. Frequencies of virulence alleles in isolates collected from infected leaves (leaf sample), or in a random sample of single colony isolates formed by airborne spores in Cambridge (roof sample).

WMR group	Frequency of corresponding virulence			
	Leaf sample		Roof sample	
	No.	%	No.	%
1	19/70	27	27/60	45
2	66/70	94	60/62	97
3a			56/63	89
3b			9/60	15
4a	57/70	81	39/60	65
4b	31/70	44	28/62	45
5	67/70	96	57/61	93
6	62/70	89	53/59	90
7	61/70	87	47/61	77
8	43/70	61	55/62	89
9	9/70	13	42/58	72
5,8,? (Tonic)	2/70[1]	3		
'Axona'	2/70	3	7/62	11
'Sona'	12/70	17	22/59	37
2,'Talent'	60/70	86	51/59	86
Pm7	69/70	99	61/62	98

[1] Two further isolates were virulent on 'Broom' but not 'Tonic'.

Table 3. Frequencies of virulence phenotypes of single colony isolates of wheat powdery mildew collected from infected leaves, defined by WMV 2, 4b, 6, 7 and 8. Phenotypes carried by three or more isolates are listed separately.

Phenotype	No.	%	Number of sites	Source varieties
2 4b 6 7	9	12	2	Apollo, Dean, Hornet, Rendezvous, Slejpner
2 4b 6 7 8	17	24	2	Cebeco 903, Escorial, Focus, Fortress, Hornet, Slejpner, ST120/84
2 6 7	13	19	3	Escorial, Fortress, Norman, Slejpner, Urban
2 6 7 8	18	26	3	Cebeco 903, Escorial, Haven, Hornet, Norman, President, Slejpner
Other	13	19		
TOTAL	70			

difference. The virulences matching the resistances most widely used in British winter wheats, WMRs 2, 4b, 6, 7 and 8, were all found at high frequencies in both samples. Of these, the virulence present at the lowest frequency was WMV4b. These virulences have presumably been selected through the widespread use of the corresponding resistances in British wheat varieties.

In previous survey reports, it was proposed that varieties with WMR7 may have additional, possibly different resistance genes (e.g. Slater *et al*. 1989). In the survey of leaf isolates, one isolate, virulent on both Ambassador (WMR7) and Galahad (WMR2), was avirulent on Hornet (WMR2,7). Four isolates were avirulent on Slejpner (WMR7,x) but virulent on Ambassador. Otherwise, the results of tests on the three WMR7 differential varieties were in agreement. Any additional resistance genes carried by Hornet and Slejpner probably have little effect against the current population of wheat mildew.

Of the less widely-used resistances tested in the 1989 survey, WMRs 3a, 4a and 5, *Pm7* and the resistance of Brock, derived from Talent, were ineffective. It is possible that the frequency of WMV5 is over-estimated in detached leaf tests, since this resistance is expressed more strongly in adult plants than in seedlings (Bennett 1984). Similarly, Talent resistance is more fully expressed in older plants (R.W. Summers, pers. comm.). WMR3b, the resistance of Axona and the unknown resistance carried by Broom and Tonic were all effective against most of the isolates tested. However, Axona, Broom and Tonic do not appear to be resistant in the field, with mildew scores of 6, 5 and 4 respectively in NIAB trials (9 = resistant, 1 = very susceptible; M. Channell, pers. comm.). WMR3b is therefore the only potential source of mildew resistance detected in the experiments described here.

Frequencies of virulence phenotypes

Frequencies of virulence phenotypes, defined by WMVs 2, 4b, 6, 7 and 8, among the leaf isolates, are given in Table 3. Four phenotypes, all of which include WMVs 2, 6 and 7, comprised 81% of the leaf isolates. These results bear out the tentative conclusion of the 1988 survey, based on results of tests with bulk isolates, that many isolates now carry all the virulences corresponding

to the five most widely-used resistance genes (Slater *et al.* 1989). Such a finding in two successive years serves to emphasise the need for new mildew resistances to be introduced into winter wheat breeding programmes.

Resistance to triadimenol

The responses of 35 roof isolates, and of two control isolates, WC22 (sensitive) and T83/62 (resistant), to triadimenol were studied. No isolate was as sensitive to triadimenol as was WC22, and 11 isolates (31%) were considerably more resistant than T83/62, forming colonies on detached leaves grown from seeds treated with 1.5 g Baytan/kg (the median effective dose for T83/62 is approximately 0.25 g/kg). No previous study of the response of single colony isolates of wheat mildew to triadimenol has been carried out in our laboratory, so these figures should be treated as a baseline for further work. As with barley mildew, many isolates are now resistant to doses of triadimenol close to those recommended for field use.

CONCLUSION

None of the five resistance genes which have been widely used in British winter wheat varieties now provide effective resistance to powdery mildew. Isolates which carry virulence corresponding to all five resistances were common in 1989. The value of diversification schemes designed to protect these five resistances is doubtful, and there is probably little advantage to be had in combining any of these five resistances in a new wheat variety. New sources of resistance should be used. Further investigation of the effectiveness of the *Pm3b* resistance in the field, and of other sources of resistance, is desirable.

ACKNOWLEDGEMENTS

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YELLOW RUST OF WHEAT

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The frequency of WYV 9 rose to 99% during the 1989 yellow rust epidemic and the combined virulence WYV 6,9, has now become widely distributed throughout the UK. The susceptibility of Hornet to WYV 6,9 isolates was confirmed in inoculated adult plant tests when isolates of this type were used for the first time.

INTRODUCTION

The principal aim of the wheat yellow rust survey is to detect increased virulence for specific resistances to Puccinia striiformis (WYR factors). In addition, specific resistances in current and new cultivars are identified. Specific resistances identified to date, the resistance genes where known, differential cultivars possessing each resistance and the year of first detection of virulence (WYV) in the UK population of P.striiformis are given in Table 1.

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

WYR	Gene	Type*	Differential Cultivar(s)**	WYV dectected
WYR 1	Yr 1	0	Chinese 166, Maris Templar	1957
WYR 2	Yr 2	0	Heine V11, Brigand	1955
WYR 3	Yr 3a + 4a	0	Vilmorin 23, Cappelle Desprez	1932
WYR 4	Yr 3b + 4b	0	Hybrid 46, Avalon	1965
WYR 5	Yr 5	0	T. spelta album	
WYR 6	Yr 6	0	Heines Kolben, Maris Ranger	1958
WYR 7	Yr 7	0	Lee, Tommy	1971
WYR 8	Yr 8	0	Compair	1976
WYR 9	Yr 9	0	Riebesel 47/51, Clement	1974
WYR 10	Yr 10	0	Moro	
WYR 11	-	A	Joss Cambier	1971
WYR 12	-	A	Mega	1969
WYR 13	-	A	Maris Huntsman	1974
WYR 14	-	A	Hobbit	1972

Additional test cultivars 1989

WYR 9	Slejpner
WYR 1,9	Stetson
WYR 6,9	Hornet
WYR 9	Kavkaz/4X Federation

* 0 = Overall A = Adult Plant

** Differential cultivars used in 1989 seedling tests are underlined.

METHODS

Methods used at NIAB for virulence tests have been described by Priestley, Bayles and Thomas 1984).

1989 isolates

The 1989 yellow rust epidemic proved even more severe and widespread than that of 1988. For the second year running the epidemic was largely associated with the susceptible cultivar Slejpner, which continued to occupy more than 20% of the national acreage.

558 samples were received, of which 117 were from Slejpner, 78 from Hornet, 28 from Fortress, between 10 and 20 from each of Avalon, Mercia, Riband, Haven, Apollo, Galahad, Gambit and Urban, and the remainder from a wide range of cultivars, including National List candidates. Isolates made from 156 samples were tested for virulence in seedling tests, using the differential cultivars indicated in Table 1. Since it was impossible to culture every one of the large number of samples received, samples were selected to represent the most relevant cultivars and to cover a wide geographical spread.

1988 isolates

20 isolates were tested on adult plants of 33 cultivars in Polythene tunnels and on seedlings of the same cultivars in controlled environment chambers. The isolates comprised four re-isolates of 1987 isolates and sixteeen new isolates from the 1988 Survey (Table 2).

RESULTS

1989 isolates

The survey is not a random population sample and changes in virulence frequency from year to year (Table 3) should therefore be interpreted with caution.

The frequency of WYV 9 rose to 99% in 1989, the second successive year in which a national epidemic centred on the widely grown and highly susceptible WYR 9 cultivar Slejpner. The frequency of WYV 4 increased in parallel with WYV 9, to reach 97%. Since the popularity of WYR 4 cultivars declined between 1988 and 1989, it appears that the increase in WYV 4 was due more to its association with WYV 9 in isolates with complex virulence, rather than active selection by cultivars with the corresponding resistance. The frequency of WYV 6 continued to fall in line with the disappearance of the once popular WYR 6 cultivars Norman and Longbow. However, if new cultivars with the combined resistance WYR 6,9 achieve popularity, the frequency of WYV 6 may be expected to rise again.

Table 2. Isolates of P.striiformis used in adult plant tests.

Isolate Code	Source Cultivar	Location	WYV Factors **
88/A1	Slejpner	Plot inoc. 87/13 ex Slejpner *	1,2,3,9,13
88/A5	Slejpner	Plot inoc. 87/66 ex Slejpner *	1,2,3,9,13,14
88/A6	Apollo	Plot inoc. 87/66 ex Slejpner *	1,2,3,9,13,14
88/A9	Brock	Plot inoc. 87/69 ex Rifle *	2,3,4,6,7,13,14
88/8	Slejpner	Lincolnshire	1,2,3,9
88/9	Slejpner	Kent	2,3,4,9
88/16	Avalon	E Scotland	2,3,4,6,9
88/18	Slejpner	Northamptonshire	1,2,3,9
88/21	Slejpner	Suffolk	2,3,4,9
88/28	Slejpner	Cambridgeshire	1,2,3,9
88/77	Brock	E. Scotland	2,3,4,6,7
88/105	Mandate	E. Scotland	1,2,3,4,6,9
88/108	Hornet	E. Scotland	1,2,3,4,6,9
88/126	Hornet	Cambridgeshire	1,2,3,6,7,(9)†
88/127	Unknown	Cambridgeshire	1,2,3,4,7
88/128	Fortress	E. Scotland	1,2,3,4,6,9
88/144	Fortress	E. Scotland	1,2,3,4,6,9
88/148	Hornet	Northumberland	1,2,3,4,6,9
88/149	Fortress	Northumberland	1,2,3,4,6,9
88/151	Gambit	E. Scotland	1,2,3,4,6,9

* See UKCPVS Annual Report for 1988
** determined from seedling tests and previous years' adult plant tests
† virulent on Hornet, but not Clement

Table 3. Virulence factor frequency (%)

WYV Factor	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
WYV 1	73	73	83	95	71	63	85	75	76	78	87	68	62
WYV 2	100	97	100	100	100	100	100	100	100	100	100	100	100
WYV 3	100	100	100	85	95	100	100	100	100	100	100	100	100
WYV 4	24	27	17	15	29	37	20	31	45	70	47	78	97
WYV 5	0	0	0	0	0	0	0	0	*	*	*	*	*
WYV 6	16	26	17	25	31	29	26	64	90	96	89	72	57
WYV 7	8	0	0	0	5	5	0	3	3	22	8	6	2
WYV 8	4	0	0	0	0	2	0	0	*	*	*	*	*
WYV 9	0	0	0	0	5	2	23	31	3	4	5	66	99
WYV 10	0	0	0	0	0	0	0	0	*	*	*	*	*
Hornet WYR 6,9								*	*	0	0	42	47
No. of isolates	26	66	30	20	42	41	63	36	29	23	52	71	156

* = differential not included in test

The frequency of virulence for Hornet (WYV 6,9), first detected in 1988 at 42% frequency, was at a similar level in 1989. However, its geographical distribution was extended from Scotland and Northumberland, where it was identified in 1988, to the remainder of the UK. Table 4 shows the source of WYV 6,9 isolates by region and stage of the season. Although total numbers of isolates from each region varied considerably, with the highest number coming from East Anglia and the lowest from Scotland and N. Ireland, it is clear that WYV 6,9 was present in a higher proportion of isolates from Scotland and the North than from more southern areas. This was most marked in the early January-March period. As the season progressed, WYV 6,9 isolates were detected more widely, reaching all regions by July. WYV 6,9 is now widespread, with obvious implications for the cultivation of WYR 6,9 cultivars, such as Hornet.

Table 4. Number of isolates possessing the virulence combination WYV 6,9, classified by Region and time of sampling. (Figures in brackets are total numbers of isolates for each Region/Period).

Period of Sampling	Scotland	N.E & Lincs	E.Anglia	S & S West	Midlands & Wales	N.Ireland
Jan-March	3(3)	1(2)	1(15)	0(2)	0(1)	0(0)
April-May	6(6)	9(9)	18(45)	3(8)	6(15)	0(0)
June-July	4(4)	9(12)	10(21)	5(8)	1(3)	2(2)
Total	13(13)	19(23)	29(81)	8(18)	7(19)	2(2)

The combination of WYV 7 with WYV 9 was detected for the first time in two isolates (WYV 2,3,4,6,7,9 and WYV 1,2,3,4,7,9). This combination, which has the potential to render ineffective one of the last remaining possibilities for cultivar diversification, will be examined in adult plant tests next year.

Adult Plant Tests

The results of adult plant tests in polythene tunnels are given in Table 5. Three isolates originally collected from Slejpner in 1987, before the major epidemic of 1988, (re-isolates 88/A1, 88/A5 and 88/A6), can be compared with five Slejpner isolates from the 1988 epidemic itself, (88/8, 88/18, 88/21, 88/28 and 88/9). There was no evidence of an overall shift in virulence for Slejpner or the other WYR 9 cultivars between 1987 and 1988 isolates. Although there was some variation between the eight Slejpner isolates in virulence for the adult plant resistances WYR 13 (M.Huntsman and Hustler) and WYR 14 (Hobbit), this was not clear cut and had no apparent influence on virulence for Slejpner. There is therefore no evidence to support the suggestion made in the 1988 Annual Report that WYV 13 might be responsible for increased virulence for Slejpner.

The nine isolates 88/126, 88/16, 88/108, 88/144, 88/148, 88/149, 88/151, 88/128 and 88/105 were all virulent on Hornet (WYR 6,9). 88/126 was the only one of these to lack virulence for the WYR 9 differential Clement in seedling tests, as discussed in the 1988 Report. Although Clement became infected in the tunnel inoculated with 88/126, this was probably due to cross-contamination, and it is noticeable that infection levels on some of the other susceptible WYR 9 cultivars (Slejpner, Gambit and Stetson), were low. Two of the Hornet-virulent isolates, 88/148 and 88/149, interacted with both Maris Huntsman (WYR 13) and Hobbit (WYR 14), giving them an outstandingly broad virulence spectrum (WYV 1,2,3,4,6,9,13,14). Isolates of this type impose severe limitations on cultivar diversification.

The two 1988 isolates shown at the extreme right of the table (88/77 and 88/127) confirmed the susceptibility of Brock to WYV 7 isolates possessing virulence for WYR 14 (Hobbit), an effect which was first noted in the 1988 report with isolate 87/69 (of which 88/A9 is a re-isolate).

Seven cultivars were included in adult plant tests for the first time. Gambit and Dean fell in the WYR 9 group of cultivars and Haven and Beaver interacted similarly to Hornet and have been classified as WYR 6,9. Urban possesses the specific resistance WYR 1 and Focus appears to possess no specific resistance (WYR 0). Results for President have been inconsistent. Initial seedling tests indicated that the cultivar possesses WYR 6, but this was not confirmed in adult plant tests, which showed no clear pattern of interactions.

There is still some doubt over the identification of the resistance of Fortress. It was observed, both in 1988 and 1989, that isolates collected from Fortress were virulent on Hornet, leading to the suggestion that Fortress, like Hornet, might possess WYR 6,9. However, the resistance of Fortress to the Hornet-virulent isolate 88/16, which lacks WYV 1, and to 88/126, which lacks WYV 4, suggests that Fortress may in fact possess the resistance factors WYR 1,4,9.

Six cultivars, with contrasting seedling resistances, maintained a high degree of adult plant resistance to all isolates (top of Table 5). Of these, only Mercia is currently widely grown (at approximately 25% of the acreage in 1989/90). Acreages of Parade, Rendezvous and Boxer are insignificant, although these cultivars could provide useful sources of resistance for breeding programmes. It is encouraging that the two new quality cultivars Pastiche and Apostle are amongst this group of resistant varieties, offering hope for the future, but there is an urgent need for improved resistance amongst high-yielding feed wheats, which must be achieved by a move away from the use of WYR 9.

FUNGICIDE INSENSITIVITY (HGCA - sponsored project)

Approximately 70 isolates of wheat yellow rust collected during 1989 were tested for insensitivity to triazoles and morpholines. There is growing evidence that isolates vary in sensitivity. On average, isolates from fungicide-treated crops showed an increase in insensitivity as compared with isolates from untreated crops. In view of current dependence on the triazole fungicides for yellow rust control, it is crucially important that monitoring of the pathogen population should continue.

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Table 5. Results of Adult Plant Tests 1989. Values are per cent leaf area infection (mean of 3 assessments)

Cultivar	WYV Factors	WYR Factors	Isolate 88/A1	88/A5	88/A6	88/8	88/18	88/21	88/28	88/9	88/126	88/16	88/108	88/144	88/148	88/149	88/151	88/128	88/105	88/A9	88/77	88/127
Parade	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Boxer	R	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Rendezvous	0 + APR	0	0	0	0	0	0	0	1	0	0	0	0	0	2	0	0	1	0	0	0	0
Pastiche	0 + APR	1	0	1	0	0	1	0	2	0	0	2	0	0	3	0	0	0	1	1	1	1
Apostle	2,6 + APR	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
Mercia	?3 + APR	0	0	1	0	0	1	1	0	2	0	0	0	1	2	1	1	0	2	2	2	3
M. Templar	1	4	1	3	2	2	2	3	4	3	4	1	3	11	8	18	11	7	8	4	0	13
M. Beacon	4	1	1	2	5	7	14	5	5	9	10	7	9	5	16	22	7	5	12	16	19	21
Brimstone	1,4	0	0	0	2	0	1	0	3	9	2	1	4	11	14	17	10	9	10	0	1	15
Avalon	4,14	1	0	0	0	1	4	1	4	4	0	4	2	3	4	11	3	4	7	10	9	11
Galahad	1,2,14	1	0	1	0	1	0	2	2	2	0	0	2	2	5	15	1	4	6	0	1	6
Kinsman	6,13	1	2	0	2	2	6	5	6	8	8	12	8	11	18	19	9	8	8	15	14	1
Norman	2,6	0	1	0	0	0	1	6	4	5	4	4	6	9	5	17	2	7	3	13	14	2
Longbow	1,2,6,13	1	0	0	1	0	0	5	5	4	1	1	7	11	11	18	3	6	0	1	1	0
President	?6	4	3	4	0	2	6	6	6	6	1	1	4	4	4	17	14	3	7	7	9	6
M. Huntsman	2,13	4	3	2	1	2	2	4	7	3	6	3	6	6	10	16	2	5	2	17	9	3
Hustler	1,2,13	11	7	13	6	3	1	9	1	1	0	6	8	8	7	21	2	3	5	2	1	4
Riband	13	10	7	11	7	5	6	10	9	2	9	4	7	7	7	16	4	6	4	12	10	8
Hobbit	14	6	6	8	7	6	10	11	13	4	8	6	5	13	13	21	7	11	13	16	14	16
Clement	9	13	13	19	15	35	31	30	24	15	18	12	12	15	15	25	14	9	8	10	11	2
Slejpner	9	11	6	11	9	10	16	15	13	4	16	7	8	16	20	4	10	9	9	3	2	1
Apollo	9	4	5	8	2	3	6	7	6	4	3	2	3	9	14	4	4	4	1	0	1	0
Gambit	9	10	8	5	5	8	12	11	14	2	12	10	5	15	21	8	5	8	8	8	2	0
Dean	9	7	3	1	4	4	9	5	10	2	3	4	3	5	14	1	2	0	0	0	0	0
Stetson	1,9	18	17	18	15	22	8	26	16	8	6	21	14	23	28	17	14	9	0	0	12	1
Hornet	6,9	1	0	0	4	1	2	0	8	13	17	9	9	15	21	11	12	11	17	0	1	3
Haven	6,9	0	1	0	1	1	1	1	10	10	5	7	15	13	19	6	8	8	2	0	2	0
Beaver	6,9	0	0	0	3	1	2	0	1	5	11	9	9	11	16	10	6	8	0	0	1	0
Fortress	1,4,9	1	2	0	2	2	6	1	0	3	0	13	13	19	23	16	16	10	4	0	0	0
Brock	7,14	0	0	0	2	0	3	4	8	2	3	3	1	3	0	2	8	12	14	14	21	
Tammy	7	2	0	0	4	1	1	5	1	11	5	1	3	4	1	1	10	22	22	32	24	
Urban	1	2	1	2	0	2	1	3	3	3	1	3	2	6	14	3	9	6	0	0	11	
Focus	0	9	8	7	2	2	2	7	11	2	6	4	9	4	15	6	4	3	15	10	4	

R = resistant to all isolates.

( ) = virulence not detected in seedling virulence tests, indicating cross contamination.

* = virulent on Hornet, but not Clement

BROWN RUST OF WHEAT

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Samples of wheat brown rust were received from 65 winter and 1 spring wheat cultivar in 1989. These included 27 samples received from the HGCA-funded MAFF cereal survey, to be further screened at E.S.C.A. for fungicide insensitivity. Adult plant field tests together with seedling test results enabled the resistances present in specific wheat cultivars to be classified. The winter wheat cvs Fortress and Apollo carry WBR-1, as do cvs Hornet, Beaver, Dean and Slejpner which appear to have additional adult plant resistance. The spring wheat cvs Wembley and Sober showed a response pattern similar to cv. Sappo (WBR-3) whilst cv. Canon appears to have additional resistance expressed at the adult plant stage. The resistance of the winter wheat cvs Apostle, Pastiche, Gambit, Rendezvous and Brimstone was effective against the isolates to which they were tested, as was that of the spring wheat cv. Axona.

GLASSHOUSE SEEDLING TESTS WITH 1989 ISOLATES

Sixty-six samples of Puccinia recondita were received in 1989. This number included 27 sent from the MAFF Cereal Survey specifically for fungicide insensitivity screening at E.S.C.A. (Dr. J. Gilmour, HGCA-funded project). One sample was from the spring wheat cv. Minaret, the rest being from winter wheat cultivars. The samples were from the following ADAS regions of England: East (40), South-West (16), East-Central (4) and South (4). The remainder came from Wales. Isolates were obtained from 49 of the samples, of which 12 have been tested on differential cultivars which comprised the standard WBR reference cultivars, cv. Thatcher backcross lines, carrying different resistance factors, and 17 other spring and winter wheat cultivars from the NIAB Recommended List and Recommended List Trials (Table 1). The remaining isolates will be tested during 1990. The tests were carried out under two post-inoculation environments, a low-temperature regime (10°C and 12 h photoperiod) and a high-temperature regime (25°C and 12 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 (WBR-2,3,4 and 7), interactions were classified as susceptible only if that reaction was expressed at both temperatures. The data are presented in Table 2.

Eight of the isolates were virulent on cv. Clement (WBR-1). The winter cvs Dean, Hornet, Beaver, Apollo and Slejpner gave a similar pattern of response.

The temperature-sensitive resistance WBR-2, present in cvs Maris Fundin, Norman and Hobbit was overcome by all the isolates.

Table 1. Differential cultivars

Standard differential cultivars		Thatcher Lr lines	Spring and Winter cultivars
Clement	(WBR-1)	Lr 1	Urban
Maris Fundin	(WBR-2)	Lr 2a	Dean
Norman	(WBR-2)	Lr 3	Beaver
Hobbit	(WBR-2)	Lr 3bg	Apostle
Sappo	(WBR-3)	Lr 3ka	Tara
Maris Halberd	(WBR-4)	Lr 9	CWW 87/3/1
Gamin	(WBR-6)	Lr 15	Hereward
Sterna	(WBR-7)	Lr 19	Canon
Sabre	(WBR-7)	Lr 24	Wembley
Armada	(WBR-0)		Hornet
			Tallon
			Sober
			Slejpner
			Pastiche
			Apollo
			Riband
			Axial

Table 2. Classification of seedling reactions of differential cultivars to 1989 pathogen isolates

Cultivar	WBR factor	Virulence combination		Virulence frequency 1987	1988	1989
C ement	1	R	S	0.11	0	0.67
Fundin	2*	S	S	0.78	0.96	1.00
Norman	2*	S	S	0.78	0.85	1.00
Hobbit	2*	S	S	0.78	0.88	1.00
Sappo	3*	R	R	0.08	0	0
Halberd	4*	R	R	0.08	0	0
Gamin	6	S	S	1.00	1.00	1.00
Sterna	7*	R	R	0	0	0
Sabre	7*	R	R	0	0	0
Armada	0	S	S	1.00	1.00	1.00
No. of isolates		4	8	36	26	12

* Temperature sensitive

The resistance of cv. Sappo (WBR-3), which is more effective at the lower temperature, was not overcome by any of the isolates at 10°C. Eight isolates did give a mixed susceptible reaction at the higher temperature. Likewise, cv. Halberd (WBR-4) was resistant to all isolates at 10°C but displayed a more susceptible reaction at 25°C. The spring wheat cvs Sober, Canon and Wembley gave a pattern of response similar to that of cv. Sappo although they appeared to be more susceptible at the higher temperatures. One isolate, WBRS-89-53, was virulent on cv. Sober at 10°C.

Cv. Gamin (WBR-6) was susceptible to all the isolates.

All the 1989 isolates were avirulent on cvs Sterna (WBR-7) and Sabre (WBR-7) at 25°C, but gave a more susceptible reaction at the low-temperature regime, two of the isolates being fully compatible with cv. Sabre.

The winter wheat cv. CWW 87/3/1 appears to have a temperature-sensitive resistance which was effective against some of the isolates at the higher temperature.

Cvs Urban, Apostle, Tara, Hereward, Pastiche, Riband, Axial and Tallon were all susceptible.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Two isolates were tested on adult plants in field isolation nurseries in 1989. The isolates used were:

Isolate	Origin
WBRS-83-50 (WBV-2,3,4,5,6,9)	Cv. Rapier, Wye, Kent.
WBRS-87-28 (WBV-1,2,5,6)	Cv. Mission, Backweston, Eire.

The virulence factors carried by the two isolates were identified from seedling tests. Previous tests using adult plants have shown WBRS-83-50 as carrying WBV-5 and 9. It may be that isolate WBRS-87-28 also carries additional virulence(s) which can only be identified at the adult plant stage of growth.

Each nursery comprised 34 winter and 9 spring wheat cultivars. Assessments of percentage infection and reaction type were made throughout the season.

Results

These are summarised in Table 3. Levels of disease were slow to build up within the nurseries, and infection was unevenly distributed. This led to wide variations in levels of infection recorded between replicates of some individual cultivars. Also 11 cultivars, which were sown later in the autumn, failed to establish in one of the nurseries due to the cold and wet conditions immediately after sowing. Using the limited data from the 1989 field nurseries together with that from previous years and seedling test results, some of the winter and spring wheat cultivars were placed into groups. Cultivars Fortress and Apollo appear to carry WBR-1, being susceptible to isolate WBRS-87-28 which carries the corresponding virulence, WBV-1.

Cultivar Slejpner has also been placed in this group although it is resistant to isolate WBRS-87-28 in the field. Seedling tests confirm that it carries WBR-1, but it also has additional resistance which is only expressed at the adult plant stage of growth. Likewise, cvs Hornet, Beaver and Dean give a similar pattern of response both in seedling and adult plant tests and are also placed in this group.

Both isolates carry virulence to WBR-2 carried by cvs Fundin, Hobbit and Norman, although infection levels on cv. Hobbit were low in the nursery inoculated with isolate, WBR-83-50. Lower levels of infection on cv. Hobbit, which is thought to carry additional resistance, have been observed previously. (Clifford et al, 1982).

Seedling test results suggest that the spring wheat cvs Wembley, Canon and Sober should be grouped with cv. Sappo (WBR-3). Cultivar Sappo was more susceptible to isolate WBRS-87-50 which carries the corresponding virulence gene, as was cv. Wembley, although disease levels were very low. However, cv. Sober displayed a similar level of susceptibility to both isolates although isolate WBRS-87-28 does not carry WBV-3. This conflicts with adult plant field test results in 1988 when cv. Sober was resistant to an isolate not carrying WBV-3. Seedling tests also revealed this cultivar to be susceptible to one isolate at the low temperature regime, whereas the other cultivars placed in this group were resistant. Further tests are required to confirm the grouping of this spring wheat cultivar. Cultivar Canon was resistant to both isolates suggesting that it may carry additional adult plant resistance.

Although showing higher levels of infection to both isolates, cvs Parade, Tonic, Minaret and Alexandria were also more susceptible to isolate WBRS-87-50. There is no evidence from seedling tests to indicate that they carry either WBR-3 or WBR-4.

Results confirm that isolate WBRS-83-50 carries virulence to cv. Maris Huntsman (WBR-5) as does isolate WBRS-87-28. Cv. Gamin (WBR-6) showed low levels of infection to both isolates in the field, although it had been susceptible in seedling tests. This pattern of response has been observed previously (Jones and Clifford, 1989).

Isolate WBRS-83-50 gave high levels of infection (31%) on cv. Avalon (WBR-9) confirming previous adult plant field tests with this isolate. This cultivar also appeared to be susceptible to isolate WBRS-87-28.

The resistance of the winter wheat cvs Apostle, Pastiche, Gambit, Rendezvous and Brimstone was effective against the isolates to which they were tested as was that of the spring cv. Axona.

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Table 3. Reactions[+] of winter and spring* wheat cultivars to specific isolates of Puccinia recondita in field isolation nurseries in 1989

Cultivar (NIAB rating)	WBR factor	Isolate WBRS-87-28 (WBV-1,2,5,6)	Isolate WBRS-83-50 (WBV-2,3,4,5,6,9)
Clement	1	20	1
Fortress		25	-
Apollo (5)		12	5
Hornet (7)	1+?	2 MS	1 MS
Beaver (4)		1 MS	-
Slejpner (9)		0	0
Dean		0	-
Fundin	2	12	21
Hobbit		15	1
Norman (6)		9	4
Sappo*	3	3	12
Wembley*		0.2	4
Sober*		8	7
Canon*	3+?	Trace	Trace
Halberd*	4	3	7
Huntsman	5	17	9
Gamin	6	2	6
Sabre	7	0	0
Sterna		0	0
Ranger	8	Trace	2
Kinsman	8?	3 MS	7
Avalon (5)	9	12	31
Apostle		0	-
Pastiche		0	-
Gambit		0	-
Rendezvous (9)		0	Trace
Axona* (9)		0.2	1
Brimstone		1 MS	2 MS
Urban		1	-
Haven (4)		1 MS	-
Galahad (3)		5 MS	4 MS
Parade		3	14
Tonic* (3)		6	24
Minaret*		11	28
Alexandria* (3)		11	29
Mercia (4)		12	8
Brock (4)		12	17
Longbow		15	11
President		18	-
Armada		15	4
Fenman		18	13
Focus		33	-
Riband (4)		33	-

[+]Mean of 3 replicates, final assessment dates (winter cvs)
" " 4 " final " " (spring cvs)
All reaction types susceptible unless stated
MS = Mixed susceptible
( ) NIAB rating: 1 = susceptible, 9 = resistant.

BROWN RUST OF WHEAT : FUNGICIDE SENSITIVITY (HGCA-sponsored project)

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The fungicide sensitivities of isolates of wheat brown rust collected during 1987 and 1988 were determined in tests with detached leaf segments and compared with those of some isolates collected before 1987. Preliminary results have been published (Boyle et al, 1988, 1989).

Further tests were completed with triadimefon and propiconazole, giving results within the range of those already reported. A selection of isolates was tested with flutriafol: there was less variation among isolates but all isolates sporulated in the presence of considerably higher concentrations of this fungicide than the other azoles.

In preliminary tests with morpholine fungicides, isolates collected in 1988 showed a wide range of responses to both fenpropimorph and fenpropidin.

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MILDEW OF BARLEY

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BMR9 (*mlo*) continued to be an effective source of resistance to barley powdery mildew. The most effective of the race-specific resistances used in British barley varieties to date, were BMR3, BMR8 and BMR10. BMVs 1a, 1b, 2a, 2b and 6a were found at high frequencies. All of the most frequent virulence phenotypes detected were complex, with virulence corresponding to several BMR groups. The sensitivity of barley mildew to ethirimol, fenpropimorph and triadimenol continued to decline. In addition to BMR9, several race-specific resistances, notably *Mlp*, may provide effective mildew resistance.

INTRODUCTION

Results of the 1988 barley powdery mildew survey indicated that the resistance genes in current use in U.K. barley breeding programmes no longer, on the whole, provide effective resistance to mildew (Slater *et al.* 1989). The outstanding exception was the continuing durability of BMR9 (controlled by the allele *mlo*) (BMR = barley mildew resistance factor; BMV = barley mildew virulence factor). The 1989 barley mildew virulence survey therefore had the following aims: (i) to monitor changes in frequencies of virulences matching mildew resistances in current use in Great Britain, in order to predict the performance of currently used resistances; (ii) to estimate frequencies of common races, in order to predict the value of diversification schemes to control barley mildew; (iii) to estimate the frequencies of virulences matching certain resistance genes which have not hitherto been used in U.K. breeding programmes, in order to evaluate the utility of these resistances as new sources of resistance.

In work on the adaptation of barley mildew to morpholine fungicides, isolates with reduced sensitivity to fenpropimorph (Corbel, Mistral) and fenpropidin (Patrol) were found in the north and east of Scotland in 1988 (Brown, Slater and See, paper in preparation). Although it was not possible to carry out a similar survey in Scotland in 1989, the frequency of reduced sensitivity to fenpropimorph was estimated in the barley mildew population in Cambridge. The responses of mildew isolates to the triazole fungicide triadimenol and to ethirimol were also studied.

MATERIALS AND METHODS

Two types of sample were collected. (i) A total of 204 single colony isolates were collected from infected barley leaves sent by UKCPVS participants (i.e. leaf isolates). Samples were received from Cockle Park, Northumberland, Driffield and Headley Hall, West Yorkshire, and Harper Adams, Shropshire. The source varieties were Gypsy (7 isolates; BMR1a,2a), Masto (7 isolates) and Pirate (7 isolates; both BMR1a,1b), Panda (6 isolates; BMR1a,2a), Magie (6 isolates; BMR1b,2a), Carrera (6 isolates; BMR1b,3), Marinka (5 isolates; BMR1b,6b), Doublet (10 isolates; BMR4,6b), Nomad (12 isolates; BMR4,8), Tyne (4 isolates; BMR4,10), Blenheim (10 isolates), Corniche (10 isolates) and Natasha (14 isolates; all BMR5,6c), Triumph (22 isolates; BMR6b,6c), Alexis (10 isolates) and Hart (9 isolates; both BMR9), Digger (27 isolates), Koala

Table 1. Differential varieties used in the survey of barley powdery mildew isolates in 1989.

BMR group	European code[1]	Resistance gene	Variety	Avirulent infection type (IT)[2]
0			Golden Promise	Susceptible control
1a	Ha	*Mlh*	W.37/136	1
1b	Ra	*Mlra*	W.41/145	0
2a	We	*Mlg*	Goldfoil	0
2a, 2b	We	*Mlg*, *Ml(CP)*	Julia	2-3[3]
3	Sp	*Mla6*	Midas	0
4	La	*Ml(La)*	Lofa Abed	2
5	Ar	*Mla12*	Hassan	0-1
6a	Kw	*Mlk*	Hordeum 1063	1
6b	Ly	*Mla7*	Porter	2
7	Al	*Mla1*	Tyra	0
6a, 8	Kw MC	*Mla9*	Simon	0[4]
9	Mlo	*mlo*	Apex	0(4)
10	Ru	*Mla13*	Pipkin	0
5, 6c	Ar Ab	*Mla12*, *Ml(Ab)*	Natasha	0-1(4)[5]
6b, 6c	Ly Ab	*Mla7*, *Ml(Ab)*	Triumph	2(4)[5]
6c, 7	Al Ab	*Ml(Ab)*, *Mla1*	Tavern	0(4)[5]
6c, 10	Ab Ru	*Ml(Ab)*, *Mla13*	Camargue	0(4)[5]

[1] Jørgensen 1990. [2] Following Moseman *et al.* 1965, except that (4) indicates a small number of IT4 colonies. [3] IT of BMR2b. [4] IT of BMR8. [5] IT of BMR6c. On all varieties, virulent IT = 4.

(3 isolates) and Pipkin (10 isolates; all BMR10) and Nugget (19 isolates; unknown resistance). The choice of isolates to be tested was weighted towards those from a BMR9 or BMR10 source variety. (ii) A random sample of 95 single colonies was taken from seedlings of Golden Promise exposed on the roof of a tall building in the centre of Cambridge at the end of March 1989, at least 2 km from the nearest field of barley (i.e. roof isolates).

Leaf isolates were tested for virulence or avirulence on detached first leaves of the varieties listed in Table 1; these carry all the resistances known to have been used in British barley varieties. The presence or absence of a virulence was determined from the infection type of the isolate of mildew (Moseman *et al.* 1965). Roof isolates were tested on a similar set of varieties, except that Igri was used instead of W.41/145 and Digger instead of Pipkin, and also on nine varieties, A222, Atlas, Black Russian, Durani, Hordeum 1402, Hordeum 1657, Nigrate, Ricardo and Rupee Gene 2, which have resistances that are not known to have been used by British barley breeders. Roof isolates were not tested on Apex.

Roof isolates were also tested for response to the following fungicides: (i) triadimenol, formulated as Baytan and applied as a powder seed dressing at 0.07, 0.12, 0.19, 0.32, 0.54, 0.9, 1.5 and 2.5 g per kg seed of Golden Promise

(the recommended field rate is 1.5 g/kg); (ii) ethirimol, formulated as Milstem and applied as a liquid seed dressing at 0.13, 0.22, 0.45, 0.67 and 1.3 ml per kg Golden Promise (field rate: 6.7 ml/kg); (iii) fenpropimorph, formulated as Corbel and applied as a spray to Golden Promise seedlings at the following concentrations: 0.025, 0.05, 0.10, 0.25 and 0.50 ml/l (recommended spray concentration: 5 ml/l).

RESULTS AND DISCUSSION

Virulence on BMR6c

Until very recently, no differential variety was available which only had BMR6c, the resistance carried by Triumph in addition to BMR6b. Four varieties were used to identify the presence or absence of BMV6c in leaf isolates: Natasha (BMR5,6c), Triumph (BMR6b,6c), Tavern (BMR6c,7) and Camargue (BMR6c,10). Serious problems arose in the identification of BMV6c. Many isolates which had BMV10 (i.e. virulent on Pipkin) and BMV6b (virulent on Porter) and were avirulent on Triumph (so, presumably, not having BMV6c) were virulent on Camargue. Similar problems arose with isolates avirulent on Triumph but virulent on Hassan (BMR5), Porter and Natasha, or virulent on Tyra (BMR7), Porter and Tavern.

It is possible either that Camargue, Natasha and Tavern have been wrongly identified as having BMR6c, or that, for unknown reasons, BMR6c is not always expressed in these varieties, or that our stock of Triumph seed is heavily contaminated with an unknown, resistant variety. We think that the latter is unlikely. Since it was difficult to identify BMV6c reliably, we have largely omitted further discussion of this virulence, except to mention that of 144 leaf isolates virulent on Porter (i.e. BMV6b), 70 were virulent on Triumph (i.e. presumably BMR6c). BMV6c is therefore probably present at a fairly high frequency in the mildew population.

A breeding line, Sv83380 (Svalöf AB, Sweden) carries BMR6c alone (Brown and Jørgensen 1990). This line could be used to ascertain the presence or absence or BMV6c in differential mildew isolates, and thus sort out some of the problems of the type described above.

Frequencies of selected virulences

The frequencies of BMVs 1a, 1b, 2a, 2b, 3, 4, 5, 6a, 6b, 7, 8 and 10, which correspond to race-specific resistances known to have been used by British barley breeders, among the roof and leaf isolates, are given in Table 2. As some of the varieties from which leaf isolates were sampled carry partly effective resistances, the BMV frequencies among leaf isolates sampled from varieties with only BMR 1a, 1b, 2a, 2b or 9 (i.e. non-selective varieties) are also given.

The most effective resistances were BMR3, BMR8 and BMR10. BMR7 was still moderately effective in the north of England. BMVs 1a, 1b, 2a, 2b and 6a were present at high frequencies; these virulences have probably been selected through the widespread use of the corresponding resistances.

Apex (BMR9) was resistant to all 204 leaf isolates, including 19 sampled from the BMR9 varieties Alexis and Hart. This indicates that BMR9 is still an effective, durable source of resistance to barley mildew in Britain, as it is throughout Europe (Andersen 1990).

Table 2. Frequencies of virulence alleles in isolates collected from infected leaves (leaf sample), or in a random sample of single colony isolates formed by airborne spores in Cambridge (roof sample).

Virulence	No. Leaf sample, all varieties	%	No. Leaf sample, non-selective varieties[2]	%	No. Roof sample	%	Weighted mean %[1]
1a	158/204	77.5	36/52	69.2	60/95	63.2	76.8
1b	199/204	97.5	49/52	94.2	89/95	93.7	93.9
2a	201/204	98.5	51/52	98.1	89/93	95.7	96.6
2b	183/201	91.0	47/51	92.2	87/89	97.8	95.7
3	29/204	14.2	12/52	23.1	11/95	11.6	15.6
4	80/204	39.2	32/52	61.5	44/95	46.3	51.7
5	139/204	68.1	43/52	82.7	48/95	50.5	61.9
6a	150/204	73.5	39/52	75.0	73/93	78.5	77.2
6b	144/204	70.6	31/52	59.6	44/95	46.3	51.0
7	15/204	7.4	10/52	19.2	30/94	31.9	27.4
8	89/203	43.6	10/52	19.2	11/94	11.7	14.4
9	0/204	0.0	0/52	0.0			0.0
10	72/204	35.3	4/52	7.7	17/95	17.9	14.3

[1] Weighted mean of frequencies among leaf sample isolates from non-selective varieties and in the roof sample.

[2] i.e. varieties without BMR 3, 4, 5, 6a, 6b, 7, 8, or 10.

Frequencies of virulence phenotypes

Table 3 lists the frequencies of virulence phenotypes, defined by BMV 1a, 1b, 2a, 2b, 3, 4, 5, 6a, 6b, 7, 8 and 10. The most common phenotype in the leaf sample, represented by 29 isolates (14.2%) collected at three sites, had BMV6a,6b,8,10, in addition to BMV1a,1b,2a,2b. This phenotype was also common in 1988, being the predominant type on BMR10 varieties (Slater *et al.* 1989). The four next most common phenotypes among leaf isolates were all collected at more than one site. In addition to BMV1a,1b,2a,2b, they carried BMV5,6a,6b (17 isolates), which was the most common type on non-selective source varieties, BMV5,6b (16 isolates), BMV4,5,6a,6b,8,10 (11 isolates) or BMV4,5,6a,6b (9 isolates). The latter phenotype has been common around Cambridge since 1986 (Brown *et al.* 1990). All of the BMV5,6a,6b and BMV5,6b isolates were also virulent on both Triumph (BMR6b,6c) and Natasha (BMR5,6c), and therefore probably have BMV6c in addition. The fourth phenotype, BMV4,5,6a,6b,8,10, has not been detected previously and is of particular concern as it carries so many of the virulences which match currently used resistances. It is only avirulent on varieties with BMR3 or BMR7.

The two most frequent phenotypes in the roof sample, from Cambridge, were comparatively uncommon among leaf isolates, which were collected in the north of England and the English midlands. These were BMV4,6a,7 (13 isolates 13.7%) and BMV1a,6a,6b,10 (8 isolates, 8.4%). Both types also had BMV1b,2a,2b.

Table 3. Frequencies of virulence phenotypes, defined by BMV 1a, 1b, 2a, 2b, 3, 4, 5, 6a, 6b, 7, 8 and 10, of single colony isolates of barley powdery mildew collected from infected leaves. Those phenotypes carried by five or more leaf isolates or by four or more roof isolates are listed separately.

Phenotype[1]	No. Leaf sample, all varieties	%	No. Leaf sample, non-selective varieties[3]	%	No. of sites	BMR of selective source varieties[2]	No. Roof sample	%
1a 4 5 6a	5	2.5	5	10	1		1	1.1
1a 4 5 6a 6b	9	4.4	5	10	3	4+6b, 6b	4	4.2
1a 4 5 6a 6b 8 10	11	5.4	0	0	2	10, Nugget	0	0.0
1a 6a 6b	3	1.5	0	0	1	6b	5	5.3
1a 6a 6b 10	1	0.5	0	0	1	10	8	8.4
1a 6a 6b 8 10	29	14.2	2	4	3	4+8, 4+10, 10	1	1.1
1a 6a 8 10	5	2.5	0	0	1	10, Nugget	2	2.1
1a 5 6a 6b	17	8.3	9	17	3	5(+6c?), 6b+6c	2	2.1
1a 5 6a 6b 8 10	6	2.9	1	2	2	4+8, 10	0	0.0
1a 5 6b	16	7.8	0	0	3	5(+6c?), 6b, 6b+6c	3	3.2
4 6a 7	3	1.5	3	6	1		13	13.7
5	5	2.5	1	2	2	5(+6c?)	3	3.2
Others	94	46.1	26	50			53	55.8
TOTAL	204		52				95	

[1] All phenotypes listed separately include BMV 1b, 2a and 2b.

[2] i.e. varieties with BMR 3, 4, 5, 6a, 6b, 7, 8 or 10

[3] i.e. varieties without BMR 3, 4, 5, 6a, 6b, 7, 8, or 10.

Isolates with the former combination are virulent on Regatta, while the latter phenotype was the second most common on BMR10 varieties in 1988 (Slater *et al.* 1989).

The complexity of the most frequent virulence phenotypes makes it somewhat difficult to propose clear recommendations for variety diversification in order to maintain the effectiveness of the most useful resistances. From the frequencies of the phenotypes given in Table 3, it appears that BMR10 varieties should not, where possible, be grown close to or as a mixture with BMR 6a, 6b or 8 varieties. Likewise, BMR7 varieties should be grown separately from those with BMR 4 or 6a. It may also be desirable to separate BMR5,6c varieties from those with BMR6b,6c.

Frequencies of unselected virulences

Frequencies of virulences corresponding to nine race-specific resistance genes which are not known to have been used in British barley varieties are given in Table 4. No isolate with *Vp* was detected, while frequencies of *Va3*, *Vc* and *V(1402)* were low. The frequency of *Vat* was moderately low. It would be useful to evaluate the field performance of lines carrying these resistance genes because they may be new sources of resistance to mildew. All five genes have been introduced into near-isogenic lines of the Swedish variety Pallas (Kølster *et al.* 1986), and are thus available to breeders in a genetic background adapted to north European conditions. *Mla3* has been introduced in a number of varieties, recently released in Sweden and West Germany (Brown and Jørgensen 1990).

Table 4. Frequencies of virulences corresponding to resistance genes which are not known to have been used by British barley breeders.

Virulence allele	Test variety	Virulent	Avirulent	Total	% virulent
Va2	Black Russian	80	12	92	87.0
Va3	Ricardo	7	86	93	7.5
Val0	Durani	60	31	91	65.9
Val1	A222	42	49	91	46.2
Vat	Atlas	19	74	93	20.4
Vc	Hordeum 1657	8	83	91	8.8
Vp	Nigrate	0	93	0	0.0
V(RG2)	Rupee Gene 2	58	35	93	62.4
V(1402)	Hordeum 1402	8	85	93	8.6

Responses to fungicides

The response of roof isolates to ethirimol was classified as being sensitive, similar to that of the control isolate CC52 (median effective dose (ED_{50}) of ethirimol less than 0.1 ml/kg), or resistant, similar to that of CC1 (ED_{50} ~ 0.6ml/kg). Eighty isolates were resistant and nine sensitive. In the last survey of the response of single colony isolates to ethirimol, in October

1985, 39 isolates were resistant and 61 sensitive (Brown, 1989). There has therefore been a highly significant increase in the frequency of resistance to ethirimol in this period ($\chi^2 = 124.9$, $p < 0.001$). Resistant isolates may have been selected through the widespread use of Ferrax (ethirimol + flutriafol) as a fungicidal seed dressing.

The response of roof isolates to triadimenol was classfied as sensitive (similar to that of CC52), of low resistance (similar to CC66, ED_{50} ~ 0.07 g/kg), moderately resistant (similar to CC107, ED_{50} ~ 0.3 g/kg) or highly resistant (similar to CC138, ED_{50} ~ 2.0 g/kg). No isolate was sensitive, while one, 13 and 79 had low, moderate and high resistance respectively. The corresponding figures for October 1985 were one sensitive and five, 27 and 67 with the three increasing levels of resistance. There has therefore been a substantial increase in the frequency of isolates with high resistance to triadimenol (pooling sensitive isolates with those with low or moderate resistance, $\chi^2 = 69.4$, $p < 0.001$). Greater resistance to triadimenol may have been selected through the continuing, widespread use of triazole fungicides to control a wide range of barley diseases, including powdery mildew.

The response of roof isolates to fenpropimorph was compared to those of CC1 (sensitive) and CC139 (less sensitive). Five of the 95 isolates tested had reduced sensitivity to fenpropimorph. Although this is the first report of isolates with reduced sensitivity to morpholine fungicides occurring in England (such isolates have been found in Scotland since 1986), the less sensitive group of isolates had a median effective dose (ED_{50}) of only 0.075 ml Corbel/l approximately. The ED_{50} of the more sensitive isolates is around 0.014 ml/l.

CONCLUSION

There is a great need for improved genetic resistance to barley mildew. This need is emphasised by the continuing increase in frequency of mildew isolates with reduced sensitivity to the three groups of systemic fungicides in current use. BMR9 (*mlo*) continues to be a durable, effective source of resistance to mildew, despite widespread cultivation of BMR9 varieties. It may be that this resistance could be introduced into more varieties, in order to control mildew, without selecting isolates with a high degree of adaptation to the resistance. Several race-specific resistances, present in well-adapted genetic backgrounds, may also be useful sources of mildew resistance. By past experience, however, it is unlikely that these will be durable once introduced into cultivated varieties.

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MILDEW OF BARLEY IN NORTHERN IRELAND

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As it was an exceptionally hot and dry year there was no difficulty in obtaining isolates. Thirty-one isolates were tested, most, as in 1988, being from the 4 + 6a + b BMR group (Table 2). Table 1 shows the cultivars used for examining the various virulences.

Table 1. Test cultivars for the detection of virulence groups

BMR group	Cultivar
0	Golden Promise
2	Zephyr
3	Midas
4	Varunda
5	Medallion
6a + b	Keg
6b + c	Triumph
7	Delta
8	Leith
3 + 4	Goldspear
4 + 5	Egmont
4 + 6a	Dram
4 + 6a + b	Klaxon
4 + 9	Atem

Table 2. Mean pathogenicity of bulk isolates in 1989 on test cultivars

BMR group	Isolate source	No	2	3	4	5	6a+b	6b+c	7	8	3+4	4+5	4+6a	4+6a+b	4+9
2	Magie	1	54	7	20	61	49	12	61	32	17	32	73	5	0
2	Frolic	2	83	76	99	91	58	25	62	47	13	10	19	50	2
2	Jennifer	1	58	40	42	120	52	42	10	30	18	35	112	95	20
1b+2+3?	Torrent	3	48	55	52	68	34	54	38	43	51	40	47	34	13
1a+b+6a+b	Marinka	1	31	16	49	29	44	62	9	11	20	74	62	29	19
7	Delta	1	52	0	27	23	50	37	64	17	0	4	21	6	0
9?	Dandy	2	120	68	82	74	41	45	45	46	95	81	41	43	4
10	Digger	2	63	32	55	109	68	56	33	97	29	32	28	38	0
4+6a	Oboe	1	24	36	155	55	*	24	26	98	5	52	119	93	0
4+6a+b	Klaxon	6	62	35	28	73	43	44	12	20	33	7	35	36	4
4+6a+b	Escort	1	61	1	57	88	51	41	41	46	3	3	57	39	0
4+6a+7	Regatta	2	56	62	81	88	52	32	66	44	35	29	9	63	3
4+9	Atem	3	82	22	46	*	25	35	8	81	31	31	1	39	4
5+6?	Prisma	3	47	13	26	*	20	17	61	30	24	59	5	50	3
?	Poisanne	1	84	29	85	66	49	69	55	61	44	32	56	69	17
?	Puffin	1	18	22	152	124	82	18	30	14	20	0	8	80	0

* missing values

Table 2 shows the values for the mean pathogenicity of the isolates. Table 3 shows the values for non-corresponding pathogenicity from 1983-85 and from 1986-89.

Values for single gene groups in 1989 were almost identical to those in 1988, again showing the relatively depressed value for BMV3. On the other hand values for combined virulences were, without exception, lower than in the previous year, when again, without exception, they had all been higher than in the year before that. It is not clear if this is a genuine effect or whether it is within the range of random variation. In spite of worries of an increase in virulence for BMV4+9 after the previous year's results (Mercer, 1989) this did not occur. Although Atem had declined in popularity compared with the previous year, pustules of mildew could be found without much searching in the small number of fields that were examined. Attempts to transfer isolates from plants of Atem to plants of Golden Promise were completely unsuccessful.

Table 3. Non-corresponding pathogenicity values in Northern Ireland from 1983 - 85 and from 1987 - 89

	BMV Characters									
Year	2	3	4	5	6a+b	6b+c	3+4	4+5	4+6a+b	4+9
1983	59	53	59	37	16	22	45	32	-	-
1984	48	45	42	40	17	24	29	38	-	-
1985	65	54	60	69	31	37	35	34	-	-
1987	92	28	63	31	39	33	12	61	30	5
1988	57	33	50	76	54	66	46	65	59	24
1989	65	35	53	77	42	38	32	32	43	5

Tests on the effectiveness of Baytan seed-treatment, begun in 1987, were continued on all isolates and again showed (Fig. 1) a smooth response curve to concentration of fungicide in 1989, but at a much poorer level of control than in either 1987 or 1988.

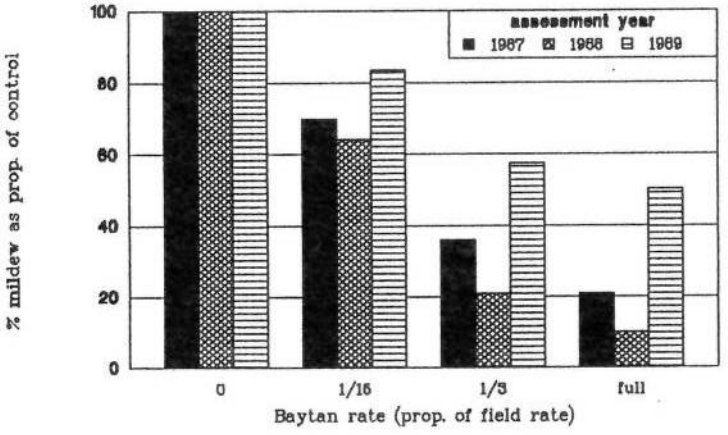

Fig. 1 Percentage of colonies of mildew growing on Baytan-treated seedlings as a proportion of those on untreated seedlings

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YELLOW RUST OF BARLEY

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Four samples were received during 1989, all samples being successfully cultured. Each isolate possessed BYV1 and BYV2, three being virulent on the BYR3 differential Triumph.

INTRODUCTION

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.

METHODS

The methods used for seedling tests and adult plant tests were similar to those described for wheat yellow rust by Priestley, Bayles and Thomas (1984).

Seedling tests with 1989 isolates

Four samples were received and successfully cultured in 1989. Two samples were received from Northumberland and two from Cambridgeshire.

RESULTS

Virulence frequencies for 1976-1989 are shown in Table 2.

Table 2 Virulence factor frequency (%)

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
BYV 1	100	100	98	-	100	100	100	100	100	-	-	100	-	100
BYV 2	0	18	32	-	54	81	96	87	100	-	-	100	-	100
BYV 3†	-	-	-	-	-	-	-	17	86	-	-	22	-	75
Number of isolates	17	27	44	1	56	52	25	30	7	1	0	9	0	4

† Not included in tests before 1983.

Three isolates were virulent on the BYR 3 differential Triumph. The frequency of BYV 3 was similar to that in 1984, despite an apparent decline in 1987.

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BROWN RUST OF BARLEY

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Samples of barley brown rust were received from 250 winter and 16 spring cultivars in 1989. These included 150 samples received from the HGCA-funded MAFF cereal survey, to be further screened at E.S.C.A. for fungicide insensitivity. The widely virulent race octal 1673 was predominant. Virulence to cv. Triumph (BBR-10) was at a lower frequency than in recent years. No new virulences or virulence combinations were detected. Contamination of the adult plant field nurseries with i) brown rust other than the isolates introduced, ii) BYDV, together with the drought conditions of 1989 rendered assessments of disease within the nurseries difficult. Quantitative differences in levels of disease on the winter barley cultivars were recorded. The spring barley cv. Alexis was provisionally placed in resistance Group IV with cv. Simon (BBR-3).

GLASSHOUSE SEEDLING TESTS WITH 1989 ISOLATES

The high incidence of barley brown rust in 1989 was reflected in the large number of leaf samples received. Two hundred and fifty were from a range of 43 winter barley cultivars and breeding lines. The remaining 16 were from spring barley cultivars. The total number included 150 samples sent from the MAFF cereal survey specifically for fungicide insensitivity screening at the East of Scotland College of Agriculture (Dr J. Gilmour, HGCA-funded project). The 250 samples received from England were from 5 different ADAS regions (Table 1).

Table 1. Geographic location (ADAS region) of 1989 barley brown rust samples

ADAS Region	Number of samples
East	102
West Central	51
South	18
South-West	37
East Central	42

The remaining 16 samples were received from Wales. The large number of samples has prevented the culture and testing of each one, 73 isolates of *P. hordei* having been tested on the standard set of differential cultivars (Table 2). Testing of the remainder of samples giving viable cultures will continue during 1990.

Results

The virulence combinations identified and their frequencies compared with the previous 2 years are given in Table 3.

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 notations
Sudan	1	Pa	1
Peruvian	2	Pa_2	2
Ribari	3	Pa_3	3
Gold	4	Pa_4	4
Quinn	5	Pa_5	5
Bolivia	6	Pa_6	6
Cebada Capa	7	Pa_7	7
Egypt 4	8	Pa_8	8
C.I. 1243	9	Pa_9	9
Triumph	10	Pa?	10

Table 3. Races and their frequencies identified from the 1989 isolates

Octal designation	BRV factors	Frequency 1987	1988	1989
1673	1,2,4,5,6,8,9,10	0.54	0.27	0.47
673	1,2,4,5,6,8,9	0.12	0.16	0.35
1653	1,2,4,6,8,9,10	0.30	0.57	0.18
1657	1,2,3,4,6,8,9,10	0.04	0	0
Number of isolates		97	60	73

The frequency of virulence to the differential cv. Triumph (BBR-10) was at a reduced level in 1989 (0.65) compared with 1988 (0.84) and 1987 (0.88). Virulence to this cultivar was first detected in 1981 and showed a rapid increase in frequency (Jones and Clifford, 1985) in subsequent years as cv. Triumph and its derivatives became more widely grown. Isolates carrying the corresponding virulence factor BBV-10 also appear to infect the majority of the currently grown winter barley cultivars more heavily.

Virulence to the differential cv. Ribari (BBR-3) was not detected in 1989.

COMPUTER DATABASE OF BARLEY BROWN RUST ISOLATES

A database of P. hordei isolates has been set up on the AGRENET VAX computer and an instruction and description booklet has been produced. This allows users to access details of barley brown rust samples received via the UK Cereal Pathogen Virulence Surveys during the 1987-88 and 1988-89 seasons. Information includes locations collected, cultivar origin and growth stage, fungicide treatments and isolate virulence classification. The availability of ampoules of vacuum-dried spores is also indicated for individual isolates with specific virulence characters (races).

(Database set up by Ms S. Heathcote and Mr P. Smith with HGCA funding).

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Two nurseries comprising 36 winter and 20 spring barley cultivars were sown in the autumn and spring of 1988-89. A third nursery was sown with spring barley only in the spring of 1987. The nurseries were inoculated

with one of the three following isolates of P. hordei.

Race octal	BRV-factors
1653	1,2,4,6,8,9,10
677	1,2,3,4,5,6,8,9
11	1,4

The less widely virulent race octal 11 was introduced into the nursery sown with spring cultivars only.

Results

Within the winter nurseries high levels of disease built up on the susceptible cultivars inoculated with race octal 1653, whereas levels were much lower in the corresponding nursery inoculated with race octal 677. The winter barley cultivars (Table 4) displayed a range of quantitative responses to both isolates which appear to be generally of a non-specific nature. With a few exceptions the cultivar rankings between isolates followed a similar pattern.

Two factors rendered assessment of disease levels within the spring nurseries very difficult. BYDV infection caused severe senescing of several of the spring barley cultivars which, together with the very dry conditions from the time of sowing, resulted in plants becoming stunted in their growth. Furthermore, interpretation of results was complicated by contamination, with a Triumph-virulent isolate (BBV-10), of the two nurseries inoculated with one or the other of the isolates race octal 11 and race octal 677. Also, disease levels were lower within the nursery inoculated with race octal 11, probably due to the other 2 nurseries having been grown alongside the corresponding winter nurseries and thus receiving additional inoculum. Nevertheless, using this limited data together with that from previous years, the spring barley cultivars were tentatively placed into resistance groups (Table 5).

The newly introduced cvs Nomad and Nugget were placed in Group II with cv. Armelle, although cv. Nomad was more susceptible to race octal 1653.

Cv. Alexis was resistant to race octal 1653 and race octal 11, but was susceptible to race octal 677. It is thus provisionally placed in Group IV together with cv. Simon (BBR-3).

The adult plant resistance of cv. Corniche was again effective against all isolates.

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Table 4. Percent infection* of winter barley cultivars with specific isolates of P. Hordei Otth. in field isolation nurseries in 1989.

Winter cultivar	Race octal 1653 BRV-1,2,4,6,8,9,10	Race octal 677 BRV-1,2,3,4,5,6,8,9
Pirate	44.0	9.0
Magie (5)	39.0	9.0
Torrent (4)	38.0	12.0
Pipkin (4)	34.0	12.0
Clarine (4)	34.0	10.0
Calix	30.0	6.0
Concert	29.0	10.0
Mimosa (4)	28.0	10.0
Plaisant	27.0	12.0
Masto	27.0	9.0
M. Otter	26.0	10.0
Vixen	26.0 MS	9.0 MS
Nevada	25.0	7.0
Kaskade	23.0	9.0
Carrera	23.0	7.0
Gerbel	22.0	11.0
Sonate	22.0	8.0
Frolic (6)	22.0	8.0
Panda (5)	22.0	7.0
Trixi	22.0	6.0
Kira (6)	21.0	7.0
Waveney (3)	20.0	5.0
Target (5)	20.0	4.0
Posaune (6)	19.0	6.0
Finesse (7)	19.0	5.0
Sarah	19.0	5.0
Igri (6)	16.0	5.0
Cashmir	14.0	9.0
Marinka (5)	14.0	7.0
Pastoral (6)	13.0	4.0
Gypsy (7)	13.0	3.0
Melusine (4)	12.0	4.0
Halcyon (5)	11.0	6 0
Gaulois (5)	8.0	4.0
Koala	7.0	6.0
Puffin (8)	7.0	3.0

*Mean of 4 replicates at 3 assessment dates (race octal 1653)
" " " " " 2 " " (race octal 677)
( ) NIAB rating: 1 = susceptible, 9 = resistant
All reaction types susceptible unless stated
MS = mixed susceptible

Table 5. Percent infection* of spring barley cultivars with specific isolates of P. hordei Otth. in field isolation nurseries in 1989.

Spring cultivar (NIAB rating)	Race octal 1653 BRV-1,2,4,6,8,9,10	Race octal 677 BRV-1,2,3,4,5,6,8,9	Race octal 11 BRV-1,4.
Group I (BBR-0)			
Midas	27	27	13
Golden Promise	20	21	9
Group II (BBR-10)			
Triumph (5)	3	4 MS	3 MS
Doublet (5)	3	5 MS	3 MS
Prisma (4)	5 MS	6 MS	3 MS
Natasha (5)	3	4	2 MS
Blenheim (4)	9	14	2 MS
Hart (4)	11	11	5 MR
Regatta (6)	6	12	3 MR
Klaxon (6)	5	9	2 MR
Joline	6	10	1 MR
Armelle	2	11	2 MS
Nomad (6)	12	14	7 MS
Nugget (7)	5	11	5 MS
Group III (BBR-5)			
Vada	5 MS	7 MS	4 MS
Atem (5)	9	10	4
Digger (5)	10	11	4
Group IV (BBR-3)			
Simon	0	10	0.2 MR
Alexis (6)	0	6 MS	0.5 R
Group V (BBR-10 + ?)			
Corniche (8)	0.2 MR	1 MR	1 MR

*Percent infection: mean of 4 replicates at 2 assessment dates (race octal 1653 and race octal 11)

*Percent infection: mean of 4 replicates at 3 assessment dates (race octal 677)

All reaction types susceptible unless stated

MS = mixed susceptible; MR = mixed resistant; R = resistant.

( ) NIAB rating: 1 = susceptible, 9 = resistant.

BROWN RUST OF BARLEY : FUNGICIDE SENSITIVITY (HGCA-sponsored project)

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The fungicide sensitivities of isolates of barley brown rust collected during 1987 and 1988 were determined in tests with detached leaf segments and compared with those of some isolates collected before 1987. Preliminary results have been published (Boyle et al, 1988, 1989).

Further tests were completed with triadimefon and propiconazole, giving results within the range of those already reported. A selection of isolates was tested with flutriafol: there was less variation among isolates but all isolates sporulated in the presence of higher concentrations of this fungicide than the other azoles.

In preliminary tests with morpholine fungicides, isolates collected in 1988 showed a wider range of responses to fenpropidin than to fenpropimorph.

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RHYNCHOSPORIUM OF BARLEY

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Two new virulence combinations were identified from the 13 isolates of Rhynchosporium secalis tested on seedlings in 1989. Both carried virulence to the differential cv. La Mesita (BRR-5), one being identified as race octal 137, the other as race octal 34, which is less widely virulent. The development of isolates with this combination of virulence is potentially significant and the situation requires careful monitoring. Seedling tests confirmed the resistance of the spring barley cv. Digger, suggesting that it has a resistance gene(s) not present in any of the other differential cultivars. Winter barley cultivars within the adult plant field nursery inoculated with race octal 0 gave a range of quantitative responses, whilst within the spring cultivars the specific resistance of cvs Armelle, Joline, Osiris and Digger was expressed. Contamination of the nursery inoculated with race octal 77 rendered assessment of Rhynchosporium disease levels very difficult.

GLASSHOUSE SEEDLING TEST WITH 1989 ISOLATES

Only 15 samples of Rhynchosporium secalis were received in 1989, a reflection of the dry spring and summer which was not conducive to the spread of this splash-borne pathogen. The infected leaf samples, 12 from winter and 3 from spring barley cultivars, were received from a range of different locations in England and Wales (Table 1). The isolates successfully cultured were inoculated onto seedlings of the 7 differential test cultivars together with 8 other spring and winter barleys. These cultivars and their resistance factors are given in Table 2.

Table 1. Geographic and cultivar origin of Rhynchosporium secalis samples received in 1989.

Sample number	Cultivar	Location
RS-89-1	Igri	Driffield, N Humberside
RS-89-2	Marinka	Holsworthy, N Devon
RS-89-3	Marinka	Hathersley, N Devon
RS-89-4	Marinka	Modbury, S Devon
RS-89-5	Magie	Blunham, Bedfordshire
RS-89-6	Alexis	Harper Adams, Salop
RS-89-7	Doublet	" " "
RS-89-8	Nomad	" " "
RS-89-9	Torrent	Chadlington, Oxon.
RS-89-10	Pipkin	Cheriton, Hampshire
RS-89-11	Marinka	Haverfordwest, Dyfed
RS-89-12	Marinka	S Brent, Devon
RS-89-13	Masto	Haverfordwest, Dyfed
RS-89-14	Maris Otter	W.P.B.S., Dyfed
RS-89-15	Maris Otter	W.P.B.S., Dyfed

Table 2. Differential test cultivars for Rhynchosporium secalis.

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

Results

The 13 isolates successfully cultured, when classified by their reaction on the differential cultivars gave a range of different virulence combinations. Each virulence combination identified has been designated an octal virulence number (Jones and Clifford, 1984) (Table 3).

Table 3. Virulence factor combinations identified from the 1989 survey.

No. of	Differential cultivars in fixed linear order							Octal vir.
isolates	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	des.
4	1	0	0	1	1	1	1	117
2	1	0	0	1	1	0	0	114
2	0	0	0	1	1	1	1	17
1	0	0	0	1	1	0	0	14
1	0	1	1	1	1	1	1	77
1	0	0	1	1	1	0	0	34
1	1	0	1	1	1	1	1	137
1	0	0	0	0	0	0	0	0

1 = susceptible, 0 = resistant

Two new virulence combinations were identified in 1989. Isolate Rs-89-10, which was identified as race octal 137, differs only from the commonly found race octal 117 in that it also carries virulence to BRR-5 (La Mesita). The isolate was cultured from an infected leaf sample of cv. Pipkin which carries the same resistance gene Rh4, as La Mesita. The second new virulence combination, race octal 34, also carries virulence to BRR-5, but is less widely virulent than isolate RS-89-10, being capable of only attacking 2 other differential cultivars, Igri and Athene.

One isolate, RS-89-14, was virulent on cv. Osiris (BRR-6), virulence to which has previously been detected in one isolate only in 1985. However, the 1989 sample was collected from a Rhynchosporium disease nursery at the W.P.B.S. which had been artificially inoculated with race octal 77, which also carries virulence to cv. Osiris. Cv. Digger was included in 1989 seedling tests as it has shown high levels of resistance in previous years' adult plant field tests. Although a few of the isolates gave low levels of infection on this spring barley cultivar it was classified as being resistant. The results suggest that cv. Digger has resistance not present in the current set of differential cultivars.

Table 4. Virulence frequency corresponding to each differential cultivar compared with previous two years.

	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	No of isol-ates
1989	0.54	0.08	0.23	0.92	0.92	0.62	0.62	13
1988	0.81	0	0	0.98	0.98	0.19	0.19	48
1987	0.46	0	0	0.59	0.75	0.16	0.16	61

Virulence to both cvs Armelle (BRR-1) and Astrix (BRR-2) was found at an increased frequency of 0.62 in 1989 (Table 4). Although these two cultivars generally show a similar pattern of response, isolates have previously been identified which are capable of only overcoming the resistance of cv. Armelle (BRR-1), suggesting that they carry a common resistance with cv. Astrix carrying an additional resistance gene(s).

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Forty winter and 21 spring barley cultivars were sown in each of 2 nurseries in the 1988-89 season. The nurseries were inoculated with one or other of the following isolates.

UK CPV Survey Code	Virulence Characteristics	Octal designation
Rs-85-50	BRV-1,2,3,4,5,6	77
Rs-89-15	BRV-0	0

The nursery inoculated with isolate Rs-89-15 was grown alongside a Rhynchosporium disease nursery used to screen breeding material and which is infected naturally. Leaf samples taken from the nursery during the season were tested on seedlings of the set of differential cultivars. The isolate was identified as race octal 0 although low levels of infection were also recorded on Armelle, Astrix, Athene, Igri and Pirate.

Results

The results are summarised in Table 5 (winter cultivars) and Table 6 (spring cultivars).

The winter cultivars showed reasonable levels of infection during late winter. Rapid growth during the very dry spring meant that disease was very slow to spread to the upper leaves of the plants, although this was better achieved in the nursery inoculated with race octal 0. This was probably due to 1) the location of the nursery being more conducive to the development of disease and 2) the exposure of the cultivars to additional inoculum from the adjoining nursery. Also, susceptible cultivars within the nursery inoculated with Rs-85-50 became heavily infected with BYDV resulting in early senescing of the plants.

Quantitative differences in levels of infection were observed between cultivars within the nursery inoculated with isolate Rs-89-15. Both cvs Igri (BRR-4) and Athene (BRR-3), with infection levels of 19% and 11% respectively, were more susceptible than would be expected from seedling test results. The winter barley cv. Hoppel again showed low levels of infection, as did cvs Astrix and Pirate, both of which carry resistance genes effective against this isolate. The newly introduced cvs Koala, Trixi and Gypsy all displayed high levels of resistance.

Spring barley cultivars within the nursery inoculated with race octal 77 were also heavily infected with BYDV, rendering assessment of any Rhynchosporium infection difficult. Cvs Armelle (BRR-1), Joline (BRR-1), Osiris (BRR-6) and Digger (BRR-?) were all resistant to race octal 0. A range of infection levels was noted on the other spring barley cultivars, Alexis being the most heavily infected (13%). Cv. La Mesita (BRR-5) was infected on its upper leaves although isolate Rs-89-15 does not carry the corresponding virulence genes. This effect has been noted previously (Clifford and Jones, 1982).

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Table 5. Percent infection* of winter barley cultivars in Rhynchosporium isolation nurseries, 1989.

Cultivar (NIAB rating)	Rs-85-50 BRV-1,2,3,4,5,6	Rs-89-15 BRV-0
Maris Otter	1	37.0
Vixen	4	26
Waveney (7)	2	20
Cashmir	2	20
Igri (7)	1	19
Clarine (7)	3	16
Frolic (7)	4	14
Tipper	6	14
Carrera	2	14
Sarah	2	14
Sonate	2	12
Kaskade	2	12
Nevada	4	12
Magie (8)	1	11
Puffin (7)	1	11
Athene	1	10
Panda (6)	5	10
Posaune (7)	2	9
Masto	4	9
Kira (7)	1	9
Torrent (8)	5	9
Halcyon (7)	2	7
Gaulois (8)	1	6
Melusine (8)	0.5	6
Calix	0.5	6
Finesse (8)	1	5
Gerbel	2	5
Plaisant	2	5
Pipkin (7)	4	4
Pirate	4	4
Gypsy (7)	1	4
Trixi	2	4
Target (8)	0.5	4
Koala	6	3
Pastoral (8)	0.5	3
Marinka (8)	0.5	3
Mimosa (8)	1	2
Concert	2	2
Astrix	1	2
Hoppel	2	1

*Mean of 2 scoring dates, 4 replicates

Table 6. Percent infection* of spring barley cultivars in Rhynchosporium isolation nurseries, 1989.

Cultivar (NIAB rating)	Rs-85-50 BRV-1,2,3,4,5,6	Rs-89-15 BRV-0
Alexis (3)	3	13
Nugget (5)	2	11
La Mesita	7	11
Doublet (3)	0.5	10
Atem (5)	2	9
Corniche (3)	0.1	9
Hart (4)	4	9
Natasha (4)	0.5	7
Golden Promise	1	7
Prisma (3)	1	5
Regatta (5)	2	5
Triumph (4)	1	4
Midas	2	4
Proctor	0.5	4
Nomad (4)	1	4
Blenheim (3)	3	3
Klaxon (5)	1	1
Digger (9)	0.5	0.5
Armelle	0.5	0.2
Joline	0.5	0.2
Osiris	1	0

*Mean of 2 scoring dates, 4 replicates

NET BLOTCH OF BARLEY

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Sixteen of the 20 leaf samples of net blotch received in 1989 were successfully tested on seedlings of the 13 differential and additional winter barley cultivars. The isolates included two from Denmark which were identified as carrying virulence factors commonly found in the UK pathogen population. One of the UK isolates gave typical 'spotting' symptoms on the susceptible differential cultivars. Seedling test results suggest that C.I. 1243 should not be grouped with cvs C.I. 6311 and C.I. 4979 as proposed in the UK CPVS 1988 Annual Report. Reasonable levels of disease built up on the winter barley field isolation nursery inoculated with a 'netting' isolate. A range of quantitative responses were recorded on the cultivars within the nursery.

GLASSHOUSE SEEDLING TESTS WITH 1989 ISOLATES

Eighteen samples of net blotch were received from winter and spring barley cultivars. In addition, two samples received from Dr Inge Moller, Denmark were included in tests. The isolates of Pyrenophora teres cultured from the leaf samples were inoculated onto seedlings of the 13 differential cultivars (Table 1), using procedures described previously (Clifford and Jones, 1989). Cv. Marinka was included in the tests together with a number of newer winter barley cultivars.

Results

Fourteen of the UK isolates were successfully tested together with the two Danish isolates. The results from these two isolates are not included in the analysis of UK virulence frequencies. The frequencies of individual virulences corresponding to resistance factors in the 13 differential cultivars together with virulence frequencies over the period 1983-1988 are given in Table 1.

Isolates tested in 1989 appeared to be less widely virulent than those of the previous season. However, virulence to two of the differential cvs, namely C.I. 9518 and Proctor, was at a higher frequency. Cv. C.I. 9518 was susceptible to 93% of isolates compared to 39% in 1988, but prior to 1988 the frequency of virulence had always been greater than 90%. Ninety-three percent of isolates overcame the resistance of cv. Proctor, although virulence to this differential has fluctuated from season to season.

The virulences identified occurred in various combinations in the different isolates, giving a range from the single virulence factor BNV-11 in two of the isolates, to the more complex and widely virulent BNV-1,4,5,8,9,10,11,12 (Table 2).

Table 1. Virulence frequencies (%) corresponding to each differential cultivar (UK CPV Surveys 1983-1988)

Code Number	Cultivar	1983	1984	1985	1986	1987	1988	1989
1	C.I. 5401	0	0	14*	0	0	28	7
2	C.I. 6311	0	22	21	39	0	72	0
3	C.I. 9820	0	0	56*	4	0	28	7*
4	C.I. 739	24	33	33	61	20	50	7
5	C.I. 1243	0	44	42	57	0	39	57
6	C.I. 4795	0	0	0	0	10	33	14
7	C.I. 4502	0	0	0	0	0	33	14
8	C.I. 4979	0	44	33	50	0	56	7
9	Proctor	52	55	90	79	30	56	93
10	Code 65 (W)	19	0	7	0	0	72	14
11	C.I. 9518 (W)	90	100	90	96	90	39	93
12	Tenn. 61-119 (W)	19	44	33	57	60	89	64
13	C.I. 9214	9	0	0	0	0	56	7*
No. of isolates tested		21	9	15	28	24	18	14

(W) = Winter cv.; *'spotting' isolates

Table 2. Virulence combinations identified in 1989 isolates

Sample no.	Cultivar and location sampled	Virulence combinations
BNS-89-1	Torrent, Harper Adams, Salop	5,9,11,12
BNS-89-2	Panda, " " "	5,9,11,12
BNS-89-3	Puffin, " " "	11
BNS-89-4	Target, " " "	9,11
BNS-89-5	Plaisant, Beverley, Humberside	9,11,12
BNS-89-6	Panda, Wolverhamptom	5,6,7,9,11,12
BNS-89-7	Magic, Leicestershire	5,7,9,11,12
BNS-89-8	Panda, Lincolnshire	6,9,11,12
BNS-89-9	Corniche, Wymondham, Norfolk	5,9,10,11,12
BNS-89-10	Alexis, " "	1,4,5,8,9,10,11,12
BNS-89-11	Concert, WPBS, Dyfed	5,9,11
BNS-89-12*	Sample 1, PBI, Cambridge	3,9,13
BNS-89-13	Sample 2, " "	5,9,11
BNS-89-14	Sample 3, " "	9,11,12

*'spotting' isolate

It has been suggested (Jones, Maeda and Clifford, 1989) that some of the differential cultivars could be grouped on the basis of similar patterns of response to isolates tested since 1983. Three groupings were proposed

1) C.I. 5401, C.I. 9820
2) C.I. 6311, C.I. 1243, C.I. 4979
3) C.I. 4795, C.I. 4502, C.I. 9214

Virulence to group 1 cultivars remains at a low level of frequency in the pathogen population, being found in only two isolates in 1989. Isolate BNS-89-12, which gives typical 'spotting' symptoms, was virulent on C.I. 9820, whilst a different isolate, BNS-89-10, was virulent on

C.I. 5401. Cv. C.I. 9820 has previously been susceptible to 'spotting' isolates (Jones and Clifford, 1986) although it is highly resistant to 'netting' isolates. Likewise, C.I. 5401 has also shown greater susceptibility to 'spotting' isolates, but was resistant to the one 'spotting' isolate identified in 1989. However, it was susceptible to isolate BNS-89-10, a widely virulent isolate cultured from an infected leaf sample of the spring barley cv. Alexis.

Within group 2 cultivars, C.I. 1243 was susceptible to 57% of the isolates, but C.I. 6311 was resistant to all isolates tested. Virulence to C.I. 6311 has always been at a relatively low level within the pathogen population with the exception of 1988. Only one isolate, the widely virulent BNS-89-10, produced a susceptible reaction on C.I. 4979. Whilst C.I. 4979 and C.I. 6311 show similar patterns of response to the 1989 isolates, the results of these tests suggest that C.I. 1243 should not be grouped with these two cultivars. It may be that all three cultivars carry a common resistance factor(s), but that C.I. 6311 and C.I. 4979 carry additional resistance factors effective against the virulence carried by this year's isolates.

Isolate BNS-89-6 overcomes the resistance carried by the group 3 cultivars C.I. 4795 and C.I. 4502. Two other isolates, BNS-89-7 and BNS-89-8, were also virulent on one or other of these cultivars, the former giving a resistant type 2 reaction (Khan and Boyd, 1969) on C.I. 4795 and a susceptible type 3 reaction on C.I. 4502. The reactions on the two cultivars were reversed when inoculated with BNS-89-8. This continues the trend observed in previous years of these 2 cultivars displaying very similar patterns of response to the isolates, thus confirming that they may carry the same resistance factor(s). It must be remembered that the line distinguishing a resistant reaction from a susceptible one is often very thin, particularly between type 2 and type 3 reactions, and is a matter of judgement on the part of the observer. Factors such as inoculum density may also play a part in determining whether a particular cultivar is assessed as resistant or susceptible. The third cultivar, C.I. 9214, provisionally placed in this group, displayed a definite resistant reaction to the isolates, with the exception of the 'spotting' isolate, BNS-89-12, which produced 3-4 type lesions. These results suggest that, although the frequency of virulence within the pathogen population has remained similar to these three genotypes since 1983, C.I. 9214 should not be grouped with C.I. 4795 and C.I. 4502.

As in 1988 there was a reduced frequency of virulence to the winter barley cv. Marinka. Virulence was first detected in 1987 in 79% of the isolates, but in 1989 only 54% of the isolates were virulent. Inoculation with the 'spotting' isolate produced a mainly resistant type reaction. The other winter barley cvs Gypsy, Clarine, Target, Fighter, Sarah, Manitou, Poacher, Paris, Shire, and CWW1273B included in the seedling lists, also displayed a mainly resistant type reaction to this isolate but were all susceptible to the 'netting' isolates.

The two isolates from Denmark both displayed 'netting' type symptoms on susceptible cultivars although one isolate had been sampled from a leaf showing 'spotting' type lesions. They were both identified as carrying BNV-5,8,9,11,12, with one of the isolates also carrying BNV-4. These virulence factors have been the most commonly found in UK pathogen populations.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Thirty-five winter and 17 spring barley cultivars were sown in each of two nurseries in 1988-89, following standard procedures (Clifford, del Buono and Jones, 1984). One nursery was inoculated with a 'spotting' isolate, BNS-85-45 (BNV-3,4,9,11), whilst the other was inoculated with inoculum bulked from net blotch infected barley volunteers, collected at the WPBS in the autumn of 1988. Subsequent seedling tests on the standard set of differentials identified virulence to 5,9 and 11.

In previous years, disease has been slow to build up on the susceptible 'spreader' cultivars within the nurseries, resulting in very low levels of infection on the test material. When disease has built up sufficiently to allow assessment it has always been very late in the season, allowing just the one score before the plants senesced. It was decided that in 1988-1989 the inoculum should be introduced into the nurseries during the autumn of sowing, with the hope that the winter 'spreader' would be infected prior to the spring growth. To achieve this, winter barley seedlings grown in whalehide pots in the glasshouse were inoculated with one or other of the isolates under laboratory conditions. Once symptoms were seen to be developing, the pots were transplanted into the spreader rows of the nurseries. The following spring the nurseries were inoculated with spore suspensions of the isolates at approximately fortnightly intervals until the plants had come into head (G.S.59).

Results

Within the nursery incoculated with the 'netting' isolate, moderate levels of disease had built up by early spring on the 'spreader'. Rapid growth in the spring resulted in the plants growing away from the infected lower leaves, but by the end of May good levels of net blotch infection were noted on the susceptible winter cultivars. Very low levels of infection within the nursery inoculated with isolate BNS-85-45 rendered it impossible to assess the test cultivars for levels of infection. The very dry and warm summer was not conducive to the development of net blotch in the spring cultivars. Low levels of infection on some of the cultivars did allow one assessment at the end of the season within the nursery inoculated with the 'netting' isolate.

Results are given in Table 3 for winter cultivars.

The winter barley cultivars displayed a range of quantitative responses from the most susceptible cv. Concert (12%) to cvs Pipkin (0.2%) and Posaune (0%) which were resistant. Cv. Marinka was highly resistant (0.5%) to the isolate, which also failed to infect it at the seedling stage. The previous year's results had shown cv. Marinka to be susceptible to an isolate carrying the corresponding virulence factor. Low levels of infection were recorded on the new cultivars under test, namely Clarine, Gypsy, Sarah and Trixi.

The very low levels of infection recorded within the spring barleys renders interpretation of the results difficult.

The reasonably high levels of net blotch infection on the susceptible spreader cultivars in the winter nursery together with the relatively low levels of infection on the majority of the tester cultivars suggests that resistance is common in current cvs. However, it must be emphasised that the isolate used in these field tests carried virulence to only 3 of the seedling differentials.

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Table 3. Percentage infection* on winter barley cultivars inoculated with Pyrenophera teres in a field nursery in 1989.

Cultivar	BNS-89-11
(NIAB rating)	(5,9,11)
Concert	12
Gerbel	6
Sonate	4
Puffin (5)	3
Masto	3
Panda (6)	3
Pirate	3
Vixen	3
Igri (5)	3
Gaulois (7)	3
Carrera	3
Kira (8)	2
Nevada	2
Frolic (8)	2
Mimosa (9)	2
Finesse (8)	2
Torrent (7)	2
Target (5)	1
Plaisant	1
Trixi	1
Koala	1
Magie (9)	1
Halcyon (8)	1
Maris Otter	1
Melusine (7)	1
Sarah	1
Gypsy (8)	1
Cashmir	1
Pastoral (8)	0.5
Clarine (6)	0.5
Calix	0.5
Kaskade	0.3
Marinka (9)	0.3
Pipkin (9)	0.2
Posaune (7)	0

*Mean of 4 replicates, 2 assessment dates

Table 4. Percentage infection* on the spring barley cultivars inoculated with Pyrenophora teres in a field nursery in 1989

Cultivar	BNS-89-11 (BNV-5,9,11)
Doublet	1.5
Alexis	1.25
Klaxon	1.00
Joline	1.00
Prisma	1.00
Regatta	0.75
Hart	0.75
Nomad	0.75
Blenheim	0.5
Corniche	0.5
Nugget	0.5
Golden Promise	0.5
Midas	0.25
Digger	0.25
Natasha	0.25
Triumph	0
Atem	0

*Mean of 4 replicates, 1 assessment date

FUNGALLY-TRANSMITTED MOSAIC VIRUSES OF BARLEY

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Of 52 samples received in 1989, 33 contained barley yellow mosaic virus (BaYMV) and 25 barley mild mosaic virus (BaMMV). Combining results from the 3 years of the survey (1987-1989) showed that BaMMV was more frequent on malting cultivars (Maris Otter, Halcyon and Pipkin) whereas BaYMV predominated amongst cultivars used for feed.

INTRODUCTION

Two mosaic viruses occur on winter barley and cause similar symptoms. Both are transmitted by the root-infecting fungus *Polymyxa graminis*. Barley yellow mosaic virus (BaYMV) occurs in Japan, China and in northern Europe; it is difficult to transmit mechanically and the optimum temperature for symptoms is below 15 C. Barley mild mosaic virus (BaMMV) is known only from Europe; it is readily transmitted mechanically and can tolerate higher temperatures than BaYMV. BaMMV was previously regarded as a strain of BaYMV (-M strain in Germany, "Streatley" strain in the UK) but the two viruses are not serologically related and are now regarded as distinct. The survey, begun in 1987, aims to determine the distribution and relative frequency of the two viruses and to detect regional or cultivar differences.

METHODS

Samples with symptoms were received during winter and spring, mostly from ADAS regional offices. Leaves were tested serologically, usually by enzyme-linked immunosorbent assay (ELISA), for the presence of both viruses.

RESULTS AND DISCUSSION

The samples received do not constitute a random survey of disease outbreaks and, in particular, much of eastern England has been poorly represented. The results must therefore be treated with some caution. Fifty-two samples in which the cultivars were known were received in 1989. BaYMV was rather more frequent than BaMMV and a small number of samples contained both viruses (Table 1). Cultivar trends were most clearly seen when results of all three years were combined (Table 2): the malting cultivars Maris Otter, Halcyon and Pipkin had a predominance of BaMMV while BaYMV was much more frequent on the remaining cultivars. Preliminary results from inoculation experiments using viruliferous zoospores of the vector suggest that this may reflect a difference in the relative susceptibilities to the two viruses amongst the cultivars but this needs confirmation.

When the origin of samples was classified as eastern or western (using the line of 1 longitude), BaMMV was more frequent in the east than the west ($X^2=8.49^{**}$), whereas BaYMV was more generally distributed (Table 3). However, this is probably because most samples of malting cultivars (20/25) came from eastern England: the statistical significance of the effect was lost when these cultivars were removed from the analysis.

Table 1. Mosaic virus samples from 1989, classified by cultivar

	BaYMV alone	BaMMV alone	Both viruses
Maris Otter	0	4	0
Halcyon	0	2	1
Pipkin	0	1	0
Igri	5	2	1
Panda	4	3	0
Plaisant	2	3	1
Magie	12	1	1
Torrent	1	0	0
Mimosa	1	0	0
Marinka	2	3	0
Frolic	0	0	2
Total	27	19	6

Table 2. Mosaic virus samples from 1987-1989, classified by cultivar

	BaYMV alone	BaMMV alone	Both viruses
Maris Otter	0	12	2
Halcyon	2	3	2
Pipkin	0	3	1
Malting cvs	2	18	5
Igri	37	7	8
Panda	17	3	2
Plaisant	9	5	3
Magie	14	2	2
Video	0	2	0
Sonja	1	0	0
Icene	0	0	1
Torrent	3	0	0
Mimosa	1	0	0
Marinka	2	3	0
Frolic	0	0	2
Feeding cvs	84	22	18
Total	86	40	23

Table 3. Mosaic virus samples from 1987-1989, classified by place of origin

	BaYMV alone	BaMMV alone	Both viruses
East	21	24	9
West	64	19	15

The incidence of mixed infections is difficult to interpret. In several detailed studies of individual fields, one of the viruses has been found to predominate but the other virus has also been present either in certain patches or in isolated plants. It is not yet clear whether there is any interaction between the two viruses.

In 1989, as in 1988, a small number of outbreaks of BaYMV occurred on cultivars Torrent and Mimosa, which were previously regarded as immune to both viruses. As yet, there is no rapid method for diagnosis of this virus variant and it is not known if any of the BaYMV isolates from susceptible cultivars were also of this type. Current European cultivars are believed to share the same, single, resistance gene and there is therefore a need to broaden the genetic basis of resistance. Japanese experience suggests that races of the virus with different specific virulences may be expected.

MILDEW OF OATS

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Twenty-six of the 40 oat mildew samples received in 1989 were successfully cultured and tested on seedlings of the differential cultivars. OMV 1,2,3 (race 5) was, as in recent years, the predominant virulence combination with 85% frequency. Race 7 (OMV 1,2,3,4) was isolated from leaf samples of 4 winter oat cultivars, 2 of which carried resistance derived from Avena barbata (OMR-4). This virulence combination, which is capable of attacking all current commercial cultivars, has been detected previously but has remained at a low level of frequency within the pathogen population.

SEEDLING TESTS WITH 1989 ISOLATES

Forty samples of Erysiphe graminis avenae were recieved in 1989 of which 20 were from winter cultivars and the remainder from cultivars of spring oats. The 29 samples received from England were from the following ADAS regions: 16 from the North, 9 from West-Central, 2 from the South and 1 from East-Central. The remaining 11 samples were from Wales. Twenty-six isolates were successfully cultured from the samples and tested on a set of differential cultivars using methods described previously (Jones and Jones, 1980).

Results

Details of the mildew samples tested are given in Table 1, and the frequency of occurrence of the various virulences detected in 1989 compared with previous years are given in Table 2. Race 5 continues to increase in frequency, with 85% of isolates tested in 1989 being identified as carrying OMV 1,2,3. This relatively complex race, which is capable of attacking all cultivars on the current NIAB Recommended list of winter and spring oats, has become prevalent in recent years and is being selected for in preference to the less widely virulent races, in particular race 3 (OMV 1,2) which has shown a decline in frequency over the same period.

Race 7 (OMV 1,2,3,4) which carries virulence to the Avena barbata (OMV 4) resistance was identified in 4 samples from a winter oat breeding nursery at the W.P.B.S., Aberystwyth. Two of the isolates were from lines which carried resistance derived from Avena barbata, the other 2 isolates being samples from cvs Solva and Aintree. This combination, the most complex detected, was first observed in 1980 from a sample cultured from cv. Orlando, also grown at the W.P.B.S. It has since been identified from samples received from other locations, but has remained at a low level of frequency within the pathogen population. The resistance (OMR-4) is not currently present in any of the cultivars being grown commercially within the UK, but a rapid increase in the frequency of the corresponding virulence can be expected if an oat cultivar carrying OMR-4 becomes widely grown.

Table 1. Locations and cultivars from which viable mildew samples were received with virulences for each sample.

Locations	Cultivars	Virulences (OMV)
ENGLAND		
North		
Cockle Park, Northumberland	Commander, 09078Cn, Dula, 09090Cn, WI7845, SV842074, 09562Cn, SV83420, Danita, Weibull 17578, Keeper, Rollo	1,2,3
West-Central		
Harper-Adams, Shropshire	Craig, Ffion, Kynon, Peniarth	1,2,3
Salford-Priors, Warwickshire	Winter Oat	1,2,3
WALES		
W.P.B.S., Dyfed	Breeding line (2)+, Solva, Aintree	1,2,3,4
	Pennal, Image, Lustre, Aintree	1,2,3
Caernarvon, Gwynedd	Commander	1,2,3

+ = value in parenthesis after cultivar name indicates number of samples received of that cultivar

Table 2. Virulence group frequencies identified from samples received in 1989 compared with years since 1979

Virulence Group	Race	Frequency (% total) 1979	1981	1983	1985	1987	1989	No. of isolates in 1989
OMV 1	2	0	0	15	0	0	0	0
1,2	3	62	68	77	37	15	0	0
1,3	4	0	0	40	0	0	0	0
1,2,3	5	38	32	8	46	85	85	22
1,2,4	6	0	0	0	4	0	0	0
1,2,3,4	7	0	0	0	13	0	15	4
No. of isolates tested		8	47	13	24	21	26	

No other virulence combinations were identified from the 1989 samples, races 2 (OMV 1), 4 (OMV 1,3) and 3 (OMV 1,2) last being detected in 1983, 1984 and 1988 respectively.

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CROWN RUST OF OATS

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Two virulence combinations were identified from the two 1989 crown rust samples. Race 236, compatible with the differential cultivars Anthony, Appler and Saia has not previously been identified in the UK. The second isolate, cultured from a leaf sample of cv. Peniarth, was previously identified in 1974.

Two samples of oat crown rust, collected from demonstration plots of the winter oat cultivars Peniarth and Solva at Haverfordwest, Dyfed, were received in 1989. The two isolates of Puccinia coronata cultured from the leaf samples were tested on the International set of 10 differential cultivars (Table 1).

Table 1. Reactions of 1989 isolates on the International set of differential cultivars

Differential cultivar	Isolate CRS-89-1	CRS-89-2
Anthony	R	S
Victoria	R	R
Appler	S	S
Bond	R	R
Landhafer	R	R
Santa Fé	R	R
Ukraine	S	R
Trispernia	R	R
Bondvic	R	R
Saia	S	S
Race	272	236

Isolate CRS-89-1, identified as race 272, was previously found in the UK pathogen population in 1974. The second isolate, cultured from a leaf sample of cv. Solva, was identified as race 236 previously undetected in the UK. This virulence combination is compatible with the differential cultivars Anthony, Appler and Saia. Neither isolate contains previously undetected virulences.

VARIETY DIVERSIFICATION SCHEMES FOR WHEAT AND BARLEY, 1990

Variety diversification schemes to reduce the spread of disease in winter wheat and spring barley 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 two schemes which follow update those in the last annual Report.

The 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 & Jenkins (1981).

The schemes currently available are for yellow rust of wheat and mildew of barley. The scheme for mildew of wheat has been suspended, 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 will be 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 UKCPVS has also examined the possibility of including brown rust in the wheat scheme. With current varieties, diversification for brown rust is not effective, but the position will be reviewed regularly. Varieties with good resistance to brown rust are available and should be grown in areas where there is a high risk of the disease occurring. Further details of specific resistances to brown rust in wheat varieties are given in the paper on 'Brown Rust of Wheat' in this and previous UKCPVS Annual Reports.

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VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN BARLEY 1990

Severe infections may result if mildew spreads between varieties which are susceptible to the same race of the pathogen. This risk is reduced if varieties with high levels of resistance are grown. Spread can be limited further by sowing different varieties in neighbouring fields, provided that they 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).
   (W) = winter variety; (S) = spring variety
2) Find this DG number under 'Chosen DG' down left hand side of table.
3) Read across table to find the risk of mildew spread for each companion DG.
   + = low risk of spread of mildew
   M = high risk of spread of mildew

DG 0
Clarine (W)
Concert (W)
Fallon (W)
Finesse (W)
Frolic (W)
Gaulois (W)
Gerbel (W)
Gypsy (W)
Halcyon (W)
Igri (W)
Jennifer (W)
Magie (W)
M. Otter (W)
Melusine (W)
Mimosa (W)
Nevada (W)
Pastoral (W)
Paris (W)
Panda (W)
Pirate (W)
Plaisant (W)

DG 0 Contd.
Posaune (W)
Sprite (W)
Target (W)
Trixi (W)
Vixen (W)
Corgi (S)
Golden Promise (S)

DG 1
Calix (W)
Fighter (W)
Masto (W)
Nugget (S)

DG 2
Alexis (S)
Atem (S)
Dandy (S)
Hart (S)

DG 3
Golf (S)

DG 4
Koala (W)
Pipkin (W)
Camargue (S)
Digger (S)
Sherpa (S)
Tyne (S)

DG 5
Cashmir (W)
Puffin (W)
Sarah (W)
Waveney (W)
Blenheim (S)
Corniche (S)
Grit (S)
Natasha (S)
Prisma (S)

DG 6
Marinka (W)
Triumph (S)
Volga (S)

DG 7
Delta (S)
Regatta (S)
Vista (S)

DG 8
Manitou (W)
Poacher (W)
Nomad (S)

DG 9
Doublet (S)
Escort (S)
Joline (S)
Klaxon (S)
Oboe (S)

DG 10
Carrera (W)
Kira (W)
Torrent (W)

Chosen DG	Companion DG 0	1	2	3	4	5	6	7	8	9	10
0	M	+	M	M	M	M	M	M	M	M	M
1	+	+	+	+	+	+	+	+	+	+	+
2	M	+	M	+	+	+	+	+	+	+	+
3	M	+	+	M	+	+	+	M	M	M	+
4	M	+	+	+	M	+	M	+	M	+	+
5	M	+	+	+	+	M	+	+	+	+	+
6	M	+	+	+	M	+	M	+	+	M	+
7	M	+	+	M	+	+	+	M	+	+	+
8	M	+	+	M	M	+	+	+	M	+	+
9	M	+	+	M	+	+	M	+	+	M	+
10	M	+	+	+	+	+	+	+	+	+	M

Note: Varieties in DG 1 have good resistance to mildew spreading from any variety and can therefore be used to diversify with varieties in all DGs, including others in DG 1.

Varieties in DG 0 are susceptible to mildew spreading from any variety and therefore do not contribute to diversification.

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VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST IN WHEAT 1990

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 high levels of resistance are grown. Disease spread can be limited further by sowing different varieties in neighbouring fields, provided that they 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). (W) = winter variety; (S) = spring variety.
2) Find this DG under 'Chosen DG' down left hand side of table.
3) Read across 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'**.

DG 1	**DG 2**	**DG 3**	**DG 4**	**DG 6**
Apostle	Apollo	Brimstone	Avalon	Brock
Boxer	Beaver	Longbow		
Fenman	Dean	Norman		
Mercia	Fortress	President	**DG 5**	**DG 0**
Parade	Gambit	Riband	Galahad	Alexandria (S)
Pastiche	Haven	Urban		Sober (S)
Rendezvous	Hornet	Axona (S)		
Tonic (S)	Slejpner	Minaret (S)		
Wembley (S)				

Chosen DG	**Companion DG**						
	1	**2**	**3**	**4**	**5**	**6**	**0**
1	+	+	+	+	+	+	+
2	+	**Y**	y	y	y	+	**Y**
3	+	y	**Y**	y	y	y	**Y**
4	+	y	y	**Y**	y	y	**Y**
5	+	y	y	y	**Y**	y	**Y**
6	+	+	y	y	y	**Y**	**Y**
0	+	**Y**	**Y**	**Y**	**Y**	**Y**	**Y**

Note: Varieties in DG 1 have good resistance to yellow rust spreading from any variety and can therefore be used to diversify with varieties in all DGs, including others in DG 1. Varieties in DG 0 are susceptible to yellow rust spreading from any variety and therefore do not contribute to diversification.