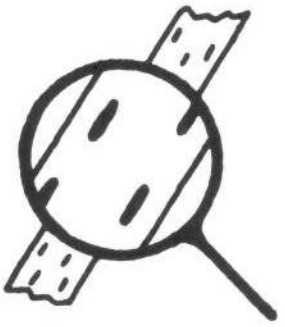
U.K. CEREAL PATHOGEN VIRULENCE SURVEY

This issue is dedicated in honour of Dr F Joan Moore O B E (Committee member 1967-1974, Chairman 1983-1986) who died on 1 March 1986.



1985 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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1985 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.

The Survey is supported financially by the Ministry of Agriculture, Fisheries and Food and the Agricultural Research Council.

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.

- Plant Breeding Institute, Cambridge for mildew of wheat and barley.

- 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 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 & Advisory Service.

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 number 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 1985

Mildew of Wheat

In 1985 WMV 2 and WMV 2+6 were again the most common pathogenicities. Seedling resistance characters in all cultivars on NIAB Recommended Lists of wheat have been matched by the pathogen. Levels of insensitivity to triazole fungicides were similar to those reached in 1984, but remained more constant throughout the year in 1985.

Yellow Rust of Wheat

The majority of isolates received in 1985 were from cultivars Longbow and Norman, both of which possess WYR 6 in combination with other resistances. The frequency of the corresponding virulence WYV 6 reached a record 90%. Results of adult plant tests confirmed that Longbow possesses the adult plant resistance WYR 13 in addition to overall resistance WYR 1,2,6. Two isolates with the complex virulence combination WYV 2,3,4,6,13,14 were identified.

Brown Rust of Wheat

The adult plant, temperature-sensitive resistances of cultivars Virtue, Hustler and Rapier remained effective in field tests. Slejpner possesses WBR 1, with additional adult plant resistance which remained effective against all isolates.

Mildew of Barley

Pathogenicity for cultivar Triumph again increased over the whole country. This rise was mirrored in N. Ireland. Insensitivity to triazoles increased markedly in eastern England and high levels of insensitivity were often associated with pathogenicity for Triumph and moderate insensitivity to ethirimol.

Yellow Rust of Barley

There was an exceptionally low incidence of yellow rust of barley in 1985 and only one sample was received.

Brown Rust of Barley

Four virulence patterns were identified from the samples received, with all but two isolates carrying virulence to cultivar Triumph. Adult plant tests in field isolation nurseries confirmed cultivar Medallion as being the only winter barley expressing resistance to the widely virulent octal race 1673, although quantitative differences in levels of infection were apparent between the other cultivars.

Rhynchosporium of Barley

Virulence to BRR 6, carried by cultivar Osiris was detected for the first time and this has important breeding implications. Several new combinations of known virulences were also identified. In field nurseries the resistance of the spring barley cvs Osiris and Digger remained effective.

Net Blotch of Barley

Samples received from Morley, Norfolk gave typical 'spotting' type lesions on seedlings tested in the glasshouse. These isolates were virulent on the differential cvs C.I. 5401 and C.I. 9820, but gave a more resistant reaction on the normally highly susceptible cv. Sonja. This pattern, whereby cultivars more susceptible to the spotting type tend to be more resistant to the typical 'netting' isolates, has been noted previously. The winter barley cv. Marinka was resistant to all isolates.

Mildew of Oats

The trend observed in recent years continued in that the predominant virulence combination was the relatively complex OMV 1,2,3 (race 5) with 46% frequency and able to attack all commercial oat cultivars. This was followed by the simpler race 3 (OMV 1,2) with 37% frequency. Four samples had virulence to Avena barbata resistance (OMR 4), which is not yet released in commerce. There was no evidence of adaptation to the very high levels of adult plant resistance in the cv. Rhiannon and a new line OM 1387.

Crown Rust of Oats

Two new virulence combinations were detected. One was identified as race 276 lacking virulence only to cvs Victoria and Saia. The other (race 256) lacks virulence to cvs Victoria, Santa Fe, Ukraine, Trispernia and Bondvic.

MILDEW OF WHEAT

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Mean pathogenicity values have changed little since 1984; WMV 2 and WMV 2+6 are still the most common pathogenicities. The contribution of background resistance in WMR 2 containing cultivars has still to be quantified, but was obviously important. Seedling resistance of all the cultivars currently on NIAB Recommended Lists of wheat has been matched by the pathogen.

Insensitivity to the triazole fungicides did not increase in 1985. Levels of insensitivity remained more constant throughout 1985 than was observed in 1984. This suggests that present triazole usage provides sufficient selection to maintain the insensitivity character at a constant level in the population. The mean infection of seedlings treated with the commercial rate of triadimenol was 5% when compared to infection of untreated seedlings.

SURVEY OF PATHOGENICITY CHARACTERS

Table 1. Wheat mildew resistance (WMR) group definitions, differential cultivars and identified resistance genes.

WMR group	Gene	Cultivar
0	-	Cerco, Hobbit, Rapier+, Moulin+, Jerico+, Minaret+
1	Pm 1	Anfield
2	Pm 2	Galahad+, Longbow+, Fenman+, Norman+, Avalon+
3	Pm 3a, 3b, 3c	Asosan, Chul, Sonora
4	Pm 4a, 4b	Khapli, Armada
5	Pm 5	Hope
6	Pm 6	Timgalen
-	Pm 7	Transec
7	Pm 8	Stuart, Ambassador+, Corinthian+
8	Mli *	Flanders, Aquila+, Mercia+
9	Pm 2 * Mld*	Maris Dove
2+4		Sappo
2+6		Brimstone+, Gawain+, Brigand+
4+8		Mission+
2+4+6		Timmo
2+6+7		CWW 1645/5
2+6+8		Crossbow
2+ Talent		Brock+, Renard+
7+ ?		Hammer, Stetson, Slejpner+
5+8+ ?		Broom+, Sicco
Sona		Wembley+, Solitaire+
Axona		Axona+
Tonic		Tonic+

* Temporary symbols
Cultivars used in differential sets underlined.
\+ Cultivars on NIAB Recommended or National Lists

In 1985 the relative frequencies of specific pathogenicity characters in the UK wheat powdery mildew populations were investigated using three methods:

1. Conventional leaf samples received from collaborators around the UK were tested to a differential set (see Table 1) in the laboratory, using the method described in a previous survey report (Bennett and van Kints, 1982).

2. Differential sets (see Table 1) of seedlings (30 seedlings of each cultivar) excluding cultivars Mission, Timmo and Broom, were exposed in the wind impaction spore trap (WIST, Bennett and van Kints, 1981). Sets were exposed each week from April to December on a 48 mile circuit of Cambridgeshire. At the height of the mildew epidemic, in June and July, sets were exposed in Scotland, Northumberland, Lincolnshire and the West Country.

3. Differential sets of seedlings (20 seedlings of each cultivar), extended to include Hobbit and cultivars on NIAB Recommended and National Lists (see Table 1), even when these cultivars possessed the same major resistance genes, were exposed on the roof of the Genetics Department, University of Cambridge. Sets were exposed for seven day periods from April to December.

After exposure in the WIST or on the Genetics Department roof, seedlings were returned to the laboratory and incubated for eight days, at 15°C, under a 16 hr light regime. Once mildew colonies had developed they were counted. Levels of mildew infection on differential and other cultivar seedlings, relative to infection of Cerco (WMR 0) seedlings, were calculated as in previous surveys. (Summers and van Kints, 1985; Bennett and van Kints, 1984b).

Table 2 gives the mean pathogenicity values for the bulk isolates from leaf samples tested to the differential set. WMV 7 was present at high frequencies only when it was selected by the presence of WMR 7 in the source cultivar. Leaf samples from cultivars without WMR 7 rarely contained this character (Table 2), even though the two other survey methods suggested WMV 7 was present in the general mildew population at a frequency of about 10% (Table 3). Unless WMR 7 was present to select for WMV 7 this character appears to be selected against. The mildew sample from the triticale Lukas did contain a high proportion of WMV 7, suggesting selection for WMV 7 by Lukas. Isolates from cultivars Wim, Socrates and Boru contained WMV Axona and WMV Tonic. More detailed analysis is required to determine if the presence of WMV Axona and WMV Tonic is due to positive selection for these virulences by these three cultivars. WMV 8 was present at high frequencies in all samples. The two other survey methods did not give such high frequencies (Table 3). Most leaf samples were obtained from NIAB Recommended and National List Trials. The mildew populations found in such trials would be complex as the cultivars in trial contain a diversity of WMR characters. The mildew populations sampled by the WIST and roof trap methods would be influenced greatly by the dominance of the commercial wheat acreage by WMR 2 and WMR 2+6 containing cultivars. It is therefore not surprising that the frequencies of WMV characters in leaf samples differed from the frequencies obtained by the other two survey methods.

Table 3 gives the relative frequencies of mean pathogenicity scores given by the three methods employed in 1985. They are compared, where possible, with 1984 figures. Note that the differential for WMR 2 has changed from Bounty to Galahad, and the differential for WMR 2+6 from Brigand to Brimstone. 1984 frequencies were also calculated relative to Hobbit, not Cerco. Comparison of the 1985 roof scores relative to Hobbit or Cerco (Table 3) demonstrate that scores relative to Cerco were consistently lower. This suggests that Cerco is more susceptible to mildew than Hobbit, even though both cultivars contain no known resistance (both are WMR 0). This difference in susceptibility must be taken into account when 1984 and 1985 figures are compared. Where comparisons between 1984 and 1985 are possible, frequencies of WMV 2 and WMV 2+6 appear to have declined. The change to Galahad

Table 2. Mean pathogenicity of bulk isolates for leaf samples received in 1985

WMR Group (source cultivars)	Wheat mildew virulence (WMV) group as represented by differential cultivars												No. of Isolates
	2	4	7	8	2+6	4+8	2+4+6	2+Talent?	5+8+?	Sona	Axona	Tonic	
0	57	38	0	102	74	45	25	55	5	25	0	5	8
2	64	18	10	99	67	20	10	67	1	10	0	0	13
7	56	21	82	110	38	20	0	60	0	0	0	0	9
8	61	0	34	118	70	0	0	63	35	73	14	0	2
2+6	57	3	0	84	76	1	0	70	0	9	0	0	7
4+8	59	72	0	95	68	71	26	50	4	17	0	5	16
2+4+6	47	66	0	54	36	49	73	28	0	71	0	0	1
2+ Talent	72	44	0	153	93	48	0	66	22	44	0	0	3
7+ ?	66	15	68	105	54	23	6	61	2	11	0	0	8
5+8+ ?	78	0	0	108	81	0	0	118	87	0	76	0	1
Axona	51	75	0	58	34	15	58	57	81	2	87	93	1
Tonic	48	43	0	48	62	32	0	55	39	0	0	51	1
? (Musket)	73	80	45	108	50	89	0	99	0	3	0	0	2
? (Ventura)	76	13	0	118	85	19	0	76	1	99	13	0	1
? (Wim)	65	48	0	93	2	52	0	51	90	2	42	75	1
? (Socrates)	49	72	0	101	15	88	0	62	92	0	72	91	1
? (Boru)	98	90	0	101	96	82	103	67	83	14	53	106	1
? (Lukas, Triticale)	0	70	78	107	0	85	0	0	0	0	0	0	1

Table 3. Mean pathogenicity scores (1984 and 1985) relative to scores on Hobbit or Cerco, for 1. Leaf isolates tested to the differential set, excluding values for samples from cultivars with matching WMR groups, 2. Mildew populations sampled using the Genetics Department roof differential set and 3. Mildew population sampled using the WIST differential set.

Sample Source	Wheat mildew virulence (WMV) group as represented by differential cultivars												No. of isolates
	2	4	7	8	2+6	4+8	2+4+6	2+Tal	5+8+?	Wembley	Axona	Tonic	
	Bounty				Brigand				Sicco				
1. Leaf 1984 (rel. to Hobbit)	72	39	8	69	82	41	24	-	28	-	-	-	67
	Galahad				Brimstone				Broom				
1985 (rel. to Cerco)	58	27	6	101	61	28	13	61	9	16	3	7	77
2. Roof 1985 (rel. to Hobbit)	87	60	13	71	84	48	-	25	9	7	7	4	30
1985 (rel. to Cerco)	67	46	10	60	62	37	-	19	7	6	6	3	30
	Bounty				Brigand								
3. WIST 1984 (rel. to Hobbit)	198	47	10	171	186	40	31	-	32	-	-	-	14
	Galahad				Brimstone								
1985 (rel. to Cerco	99	62	9	51	112	-	-	48	-	4	1	3	22

Table 4. Mean pathogenicity scores (1985) for WMR 2 cultivars exposed on the Genetics Department roof, relative to scores on Cerco.

	Galahad	Longbow	Fenman	Norman	Avalon
Mean pathogenicity relative to Cerco	67	74	93	93	113

and Brimstone, whose background resistance may differ from Bounty and Brigand may be responsible for the observed reduction in frequency of WMV 2 and WMV 2+6. Table 4 compares the relative frequencies of pathogenicity to five WMR 2 containing cultivars. The values are different, suggesting that factors other than WMR 2 are important in determining the resistance of these cultivars to mildew. Variation in background resistance in WMR 2 containing cultivars has been reported previously (Bennett, 1981). WIST surveys of Scotland, Northumberland, Lincolnshire and the West Country found no evidence that the mildew population structure, in terms of pathogenicity, varied in different parts of the UK. There are no cultivars on the NIAB Recommended or National Lists whose seedling resistance has not been matched by the pathogen.

Thirty four single colony isolates obtained from seedlings of the cultivars Axona and Tonic, after they had been exposed in the WIST or on the Genetics Department roof, were tested to the differential set. The tests demonstrated that resistance in these two cultivars was different. Although some isolates were able to infect both Tonic and Axona others could only infect Tonic or Axona, not both. Mildew which can infect the previously resistant hexaploid wheat line MD 55-286-2 (Bennett and van Kints, 1984a) was found in 1985.

SURVEY OF FUNGICIDE INSENSITIVITY CHARACTERS

The development of fungicide insensitivity to the triazole fungicides was assessed in 1985 by exposing sets of seedlings grown from treated seed (60 seedlings per treatment) in the WIST. Sets were exposed each week on the 48 mile circuit of Cambridgeshire.

Table 5. Details of fungicide set exposed in WIST, 1985

Cultivar	Seed treatment (g triadimenol kg^{-1})
Cerco	0
Cerco	0.04
Cerco	0.125
Cerco	0.25
Cerco	0.375*

* Commercial rate of triadimenol

The results obtained for fungicide insensitivity are therefore comparable to direct scores obtained in previous surveys (Summers and van Kints, 1985). The level of triazole insensitivity was similar to levels in 1984, where comparisons were possible (Table 6).

Table 6. Mean infection of Cerco seedlings grown from triadimenol treated seed, relative to infection of untreated Cerco seedlings (values are means of direct scores obtained by exposing Cerco seedlings in the WIST, each week between May and August, 1983-85).

Year	Seed treatment (g triadimenol kg^{-1} seed)			
	0.04	0.125	0.25	0.375
1983	51	18	-	-
1984	69	33	-	-
1985	66	32	14	5

In 1985 the set of seedlings exposed in the WIST included seedlings grown from seed treated with higher concentrations of chemical than sets used in previous years (0.25 and 0.375 g triadimenol kg^{-1} seed). The results from the 1985 WIST survey of fungicide insensitivity found that the population generated some colonies which grew on seedlings treated at these higher rates. This confirms the results from indirect tests carried out in previous surveys (Summers and van Kints, 1985). Unlike 1984 there was no evidence from the WIST survey that levels of insensitivity increased throughout the growing season. The similarity in the overall levels of insensitivity found in 1984 and 1985 indicates that present usage of triazole fungicides provides sufficient selection to maintain the insensitivity character at a constant level in the mildew population.

The analysis of single colony isolates obtained from cultivars containing WMR 2 or WMR 4 provided some evidence that the negative association between WMV 4 and triazole insensitivity, reported in 1983 and 1984 (Bennett and van Kints, 1984; Summers and van Kints, 1985) had persisted. The majority of the 33 isolates obtained from Armada (WMR 4) and Mission crops (WMR 4+8) were more sensitive than the isolates obtained from Norman (WMR 2). However three isolates from Armada and Mission crops were almost as insensitive as the most insensitive isolates from Norman crops. Mildew isolates containing WMV 4 and insensitivity to triazole fungicides can therefore occur.

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YELLOW RUST OF WHEAT

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Forty samples were received in 1985, from which 29 isolates were made. Nearly all possessed WYV 6, reflecting the popularity of cultivars with the corresponding resistance WYR 6. In Polythene tunnel tests, isolates with WYV 1,2,4 were virulent on Brimstone and Fenman. There was confirmation that Longbow possesses the adult plant resistance WYR 13, in addition to the overall resistances WYR 1,2,6. Two isolates with the complex virulence combination WYV 2,3,4,6,13,14, were identified.

INTRODUCTION

The principal aim of the wheat yellow rust survey is to detect increased virulence for specific resistances to Puccinia striiformis, both of the overall and adult plant types. At the same time, specific resistances present in current and new cultivars are identified and the information used to construct a varietal diversification scheme. Specific resistances (WYR factors) identified in wheat cultivars 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 Factor	Gene	Type*	Differential Cultivar(s)**	WYV detected
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 1985				
WYR 1,4			Brimstone	
WYR 1,2,4			Fenman	
WYR ?2,4+x			Mission	

* 0 = Overall A = Adult Plant. Overall resistances are effective at all growth stages, adult plant resistances are ineffective at seedling growth stages.
** Differential cultivars used in 1985 seedling tests are underlined

METHODS

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

1985 isolates

Forty samples were received during 1985, mostly from a restricted area of South Lincolnshire and North Norfolk, where severe infections in commercial crops had had been widely reported.

The samples had been collected from Longbow (14 samples), Norman (7), Brigand (4), Gawain (3) and 11 other cultivars.

Isolates were made from 29 samples. Seedling tests, using the differential cultivars indicated in Table 1, were carried out to detect virulence for specific resistances effective at the seedling stage.

1984 and control isolates

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

Code	Source Cultivar	Site	WYV Factors
Control Isolates			
71/493	Capta	Duns, Scotland	1,2,3,7
72/852	Maris Ranger	Market Harborough, Leics	2,3,4,6,12
P75/27	Hobbit	PBI Cambridge*	2,3,4,14
P79/4	TL 363/30/2	PBI Cambridge	1,2,3,14
P81/12	CWW 1684/15	PBI Cambridge	2,3,4,6,(12),13,14
81/34	Vuka	Sparsholt, Hampshire	2,3,4,9
82/29	Stetson	Wye, Kent	1,2,3,9
83/10	Hammer	Oxford	1,2,3,9
83/62	Longbow	Norfolk	1,2,3,6,13
83/A3	Longbow	NIAB Cambridge*	1,2,3,6,(13)
New Isolates			
84/1	Brimstone	N.R.P.B., Lincolnshire	1,2,3,4,6
84/A5	Brimstone	NIAB Cambridge*	1,2,3,4
84/2	Longbow	Kings Lynn, Norfolk	1,2,3,6
84/3	Longbow	Witham, Lincolnshire	1,2,3,6
84/5	Longbow	Spalding' Lincolnshire	1,2,3,6
84/6	Longbow	Kirton, Lincolnshire	1,2,3,6
84/11	Longbow	Wrangle, Lincolnshire	1,2,3,6
84/12	Longbow	Goole, Humberside	1,2,3,6
84/13	Norman	Terrington, Norfolk	1,2,3,6
84/31	Brigand	Shoreswood, Northumberland	2,3,4,6
84/39	Gawain	Wilton, Northumberland	2,3,4,6
P84/F	Norman	PBI Cambridge	1,2,3,4,6

* from inoculated plots.

Twenty two isolates were tested on adult plants of 36 cultivars in Polythene tunnels and on seedlings of the same cultivars in controlled environment chambers. The isolates comprised ten control isolates of known virulence and twelve new isolates (Table 2).

Adult plant tests were sown on 30 October 1984, inoculated on 22 March and 11 April 1985 and assessed for percentage leaf area infected on 9 May (GS 60), 21 May (GS 64) and 4 June (GS 76).

RESULTS

1985 isolates

Since sampling procedures do not constitute a random population survey, the virulence frequency figures for 1976-1985 (Table 3) should be interpreted with caution. In 1985 there was a sharp drop in the frequency of WYV 9, due to a move away from sampling Stetson and other WYR 9 cultivars. The frequency of WYV 6 increased to a record 90%, reflecting the commercial popularity of the two WYR 6 cultivars Longbow and Norman and the preponderance of isolates originating from these cultivars. 75% of the WYV 6 isolates were of the WYV 1,2,3,6 or WYV 1,2,3,4,6 types, virulent on seedlings of Longbow. The remainder possessed the virulence combination WYV 2,3,4,6. There was a slight increase in virulence for Brimstone (WYR 1,4) and Fenman (WYR 1,2,4).

Table 3 Virulence factor frequency (%)

WYV Factor	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
WYV 1	92	73	73	83	95	71	63	85	75	76
WYV 2	100	100	97	100	100	100	100	100	100	100
WYV 3	100	100	100	100	85	95	100	100	100	100
WYV 4	12	24	27	17	15	29	37	20	31	45
WYV 5	0	0	0	0	0	0	0	0	0	*
WYV 6	4	16	26	17	25	31	29	26	64	90
WYV 7	0	8	0	0	0	5	5	0	3	3
WYV 8	2	4	0	0	0	0	2	0	0	*
WYV 9	6	0	0	0	0	5	2	23	31	3
WYV 10	0	0	0	0	0	0	0	0	0	*
Additional Cultivars 1985										
Brimstone									3	10
Fenman									3	14
Mission										14
No of isolates tested	52	26	26	30	20	42	41	63	36	29

1984 isolates

Adult plant infection data and seedling reactions are summarised in Table 4. The identification of specific resistances is based not only on the 1985 results presented here, but also on previous years' results using other isolates. Since all recent test isolates have possessed WYV 3, it has not been possible to detect the presence of WYR 3 in new cultivars and this WYR factor is therefore omitted. Boxes in the body of the table are used to draw attention to apparent cultivar x isolate interactions in adult plants and have no statistical significance.

Five new cultivars, Mercia, Parade, Slejpner, Ambassador and Corinthian, were included in UKCPVS tests for the first time in 1985. Mercia and Parade showed a high level of adult plant resistance to all isolates, although Mercia was susceptible at the seedling stage and Parade resistant. Evidence from the Plant Breeding Institute indicates that Mercia possesses the resistance WYR 3, which would be ineffective against the entire 1985 set of isolates [R. Johnson, pers. comm.]

Slejpner, Ambassador and Corinthian interacted with isolates possessing WYV 9 (Box D). It appears that Ambassador and Corinthian possess good adult plant resistance in addition to the specific resistance WYR 9, whereas Slejpner has relatively poor resistance and could become a risk if too widely grown.

Increased virulence for Brimstone and Fenman was detected in adult plant tests with isolates possessing WYV 1,2,4 (Box A). Isolates with this virulence combination had previously been demonstrated to be virulent on seedlings of the two cultivars (Bayles and Thomas, 1985). Levels of infection on Fenman remained low, justifying its retention in DG 1.

Longbow interacted clearly with isolates in Box C, all of which, with the exception of one isolate from Norman, were from Longbow itself. These isolates possessed WYV 1,2,6 and also gave increased infection on the WYR 13 cultivars Maris Huntsman and Hustler, thus confirming the identification of the specific resistance of Longbow as WYR 1,2,6,13. The recent increase in susceptibility of Longbow, which appeared to accompany its rise in popularity, was probably therefore due to an increase in the frequency of the corresponding virulence combination WYV 1,2,6,13, compared with that of the simpler WYV 1,2,6, which produces relatively low levels of infection on the cultivar.

Two isolates from Brigand and Gawain, 84/31 and 84/39, (Box B) displayed the wide virulence spectrum WYV 2,3,4,6,13,14, first reported in a survey sample in 1984 (Bayles & Thomas, 1985). Isolates of this type have the ability to infect a large proportion of popular cultivars, including Avalon, Rapier, Brigand, Gawain, Moulin, Norman and Maris Huntsman. The addition only of WYV 1 to this virulence combination would produce a race capable of infecting the majority of the current winter wheat acreage.

Results for all other cultivars and isolates were consistent with those reported in earlier UKCPVS Annual Reports.

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Table 4 Results of Adult Plant Tests 1985. Values are percent leaf area infection (mean of 3

Underlining indicates a susceptible reaction in seedling tests (type >2.0).

Cultivar	Isolate and WYV Factors / WYR Factors	84/A5 1,2,3,4,	P84/F 1,2,3,4,6,(14)	84/1 1,2,3,4,6,(14)	P81/12 2,3,4,6,13,14 (con 7)	84/31 2,3,4,6,13,14	84/39 2,3,4,6,13,14	75/27 2,3,4,14	P79/4 1,2,3,14	72/852 (2)3,4,6,12	83/A3 1,2,3,6	84/2 1,2,3,6,(13)	84/12 1,2,3,6,13	84/3 1,2,3,6,13
Aquila	R?	0	0	1	1	1	1	0	0	0	0	0	0	0
Boxer	R?	0	0	0	0	0	0	0	0	0	0	0	0	0
Mercia		0	0	2	1	1	0	0	0	1	2	0	1	0
Mission	2,4	0	0	0	0	0	0	0	0	0	0	0	0	0
Parade	R	0	0	0	0	0	0	0	0	0	0	0	0	0
Brimstone	1,4	6	12	11	3	0	1	0	0	0	0	0	0	0
Fenman	1,2,4	1	2	5	2	0	0	0	0	0	0	0	0	0
Maris Beacon	2,4	10	22	26	23	24	11	24	0	3	3	0	1	0
Hobbit	14	0	3	5	4	6	6	13	15	1	0	1	1	0
Avalon	4,?14	2	5	6	3	9	5	9	0	2	0	0	2	0
Rapier	2,4,14	1	1	0	13	5	7	2	0	0	0	0	0	0
Brigand	2,14,?13	1	2	3	24	15	18	7	7	4	2	1	1	4
Gawain	2,14,?13	2	2	8	24	14	12	6	5	2	1	6	1	8
Galahad	1, 14	0	0	0	0	0	0	0	5	0	0	0	0	0
Moulin	6,14	0	1	1	10	8	8	1	0	1	0	0	0	2
Maris Ranger	6	0	11	8	20	7	12	0	0	12	4	8	8	13
Kinsman	6	4	6	8	25	20	21	0	7	11	16	19	10	33
Norman	2,6	0	18	12	17	9	3	0	0	1	10	9	11	24
Longbow	1,2,6,13	0	5	5	3	4	2	0	0	4	7	11	10	20
Hustler	1,13	3	1	3	5	2	4	0	0	1	0	7	7	24
Maris Huntsman	2,13	4	3	5	18	18	11	2	3	2	0	2	13	25
Clement	9	3	0	6	0	0	0	0	0	0	0	0	0	4
Slejpner	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Hammer	9	0	0	0	0	0	0	0	0	0	0	0	1	0
Stuart	9	1	0	0	0	0	0	0	0	0	2	0	0	0
Ambassador	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Corinthian	9	0	0	0	0	0	0	0	0	0	0	0	0	0
Stetson	1,9	2	0	3	0	0	1	0	0	0	0	0	0	0
Armada	12	0	0	0	3	2	2	0	0	10	1	0	0	0
Mega	12	0	3	5	5	6	4	0	0	12	0	0	1	0
Tommy	7	0	0	0	10	0	0	1	0	0	0	0	0	0
Brock	7	0	0	0	3	0	0	0	0	0	0	0	0	0
Renard	7	1	0	0	1	0	0	0	0	0	0	0	0	0
Maris Templar	1	8	14	13	4	1	0	0	12	2	4	4	9	14
Cappelle-Desprez		1	8	11	13	3	3	6	9	9	4	3	1	16
Michigan Amber	0	18	30	25	30	21	22	21	15	20	15	22	23	27

A

B

assessment dates)

84/11	83/62	84/5	84/6	84/13	83/10	82/29	81/34	71/493
1,2,3,6,13	1,2,3,6,13	1,2,3,6,13	1,2,3,6,13	1,2,3,6,13	1,2,3,9	1,2,3,9 (con 13,14)	2,3,4,9	1,2,3,7
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
1	0	1	0	2	0	1	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0
0	1	1	1	2	2	3	[17]	0
1	1	1	0	1	1	8	2	0
0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	2	0
2	5	5	3	6	0	7	4	0
5	5	6	2	10	1	8	3	1
0	1	1	1	0	0	3	0	0
0	0	1	0	0	0	0	0	0
10	13	10	15	8	0	2	2	1
31	20	21	13	21	0	9	14	2
21 C	17	10	10	20	0	1	1	1
24	21	20	15	19	0	4	2	0
17	18	17	14	16	8	3	1	5
11	16	14	17	13	7	11	3	3
0	0	2	1	2	31	41	22	0
0	0	0	0	0	10	20	7	0
0	0	0	0	0	6	6	3	0
0	0	0	0	0	21 D	16	9	0
0	0	0	0	0	1	0	1	0
0	0	0	0	0	3	2	0	0
0	0	1	0	1	34	23	1	0
0	0	0	0	0	0	0	2	0
0	0	0	0	0	0	0	4	0
0	0	0	0	0	0	2	0	[24]
0	0	0	0	0	0	0	0	[2]
0	0	0	0	0	0	0	0	[1]
10	13	20	10	11	5	14	4	8
8	5	7	10	13	2	9	5	6
20	20	14	19	18	11	15	14	7

( ) = partial virulence

con = contamination

R = resistant to all isolates

R? = specific resistance factors unidentified

BROWN RUST OF WHEAT

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Six isolates of Puccinia recondita were tested on seedlings of 36 winter and spring wheat cultivars, under both a low (10°) and high (25°) temperature regime. The resistance of the winter wheat cvs Corinthian and Ambassador was effective at both temperatures to all isolates. Adult plant tests in field isolation nurseries identified several winter and spring wheat cultivars with resistance effective against virulences WBV-1,2,3,4,5,6,9.

SEEDLING TESTS WITH 1985 ISOLATES

Only three samples from cv. Avalon and one each from cvs Boxer, Brock and Maris Ranger were received in 1985.

The isolates of Puccinia recondita were tested on the standard set of differential cultivars. Also included were cv. Thatcher backcross lines carrying different resistance factors, and 7 other lines received from Australia (Clifford & Jones, 1984). The winter wheat cvs Moulin, Gawain, Slejpner, Boxer, Hammer, Brock, Brimstone, Ambassador and Mercia were included in the seedling tests. The tests were conducted under two different post-inoculation environments; a low temperature regime (10°C and 12 h photoperiod) and a high temperature regime (25°C and 16 h photoperiod).

Results

Two of the isolates were virulent on cv. Clement (WBR-1). Cvs Slejpner and Hammer were also susceptible to these isolates, suggesting that they carry the same resistance.

One isolate gave an intermediate response on cvs Maris Fundin, Norman and Hobbit at both temperatures: the other five isolates were virulent. Cv. Sappo (WBR-3) was resistant to all isolates at the low temperature regime, but was susceptible at 25°C. No isolate was fully compatible on cv. Halberd (WBR-4) at either temperature regime. Isolate WBRS-85-1 gave a mixed susceptible reaction on cv. Sabre at 10°C, otherwise this cultivar, together with cv. Sterna (WBR-7), was resistant to all of the isolates at both low and high temperatures.

In the Thatcher-Lr backcross lines, resistance conferred by Lr 1, Lr 3bg, Lr 9 and Lr 19 was effective against all isolates tested and, of the lines received from Australia, Gatcher (Lr 27), CS 70 Ag#11 (Lr 29), and Thew (Lr 20) expressed a resistant reaction at 10°C but not at 25°C.

The winter cvs Corinthian and Ambassador were resistant to all six isolates at both temperatures whereas cvs Brock, Brimstone, Moulin and Boxer were uniformly susceptible.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Winter and spring wheat cultivars were grown in each of two isolation nurseries in 1984-85 using standard procedures. The two isolates used were:

Isolate	Virulenc factors	Origin
WBRS-80-1	1,2,3,4,6,9	ex. Brigand, Peterborough
WBRS-84-1	3,5,6,9	ex. Virtue, Seale-Hayne

Three replicates of each winter and four replicates of each spring cultivar were grown in each nursery and the specific isolates introduced. Assessments of percentage infection and reaction type were made throughout the season.

Results

These are summarised in Table 1. The previous grouping of cultivars according to their resistance factors was confirmed. Differences in levels of infection on the WBR-2 cvs. Maris Fundin and Hobbit were observed, confirming previous years' observations (Clifford et al., 1982) that Hobbit carries an additional resistance factor(s).

Isolate WBRS-80-1 failed to differentiate the cvs Galahad and Longbow although previous tests using this isolate in polythene tunnels at the NIAB, Cambridge (Bayles & Thomas, 1985) had done so.

The adult plant, temperature-sensitive resistance of cv. Virtue remained effective to isolate WBRS-84-1 which originated from this cultivar.

The resistance of the winter wheat cvs Gawain, Brimstone, Slejpner, Corinthian, Ambassador, Moulin, Rapier and Hustler, and the spring cultivars Axona, Jerico, Venturia and Broom was effective against both isolates. Controlled climate tests with 1985 isolates indicated that cv. Slejpner carries WBR-1 although in the field it was resistant to WBRS-80-1 which carries WBV-1 as confirmed by its reaction with cvs Clement, Stetson and Aquila. Further tests are required to resolve this difference.

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Table 1. Results of adult plant tests to specific isolates of Puccinia recondita in field isolation nurseries

Cultivar	WBR factor	Isolate WBRS-84-1 x (%)	Isolate WBRS-80-1 x (%)
Clement	1	Tr	12.0
Stetson		0.1	14.0
Aquila		0.5	6.0
Fundin	2	7.0	12.0
Hobbit	2	2.0MS	1.0MS
Sappo*	3	27.0	21.0
Halberd*	4	4.0	13.0
Huntsman	5	13.0	6.0
Brigand	5	9.0	4.0
Gamin	6	8.0	6.0
Sabre	7	0	0
Sterna	7	0	0
Maris Ranger	8	0.5MS	3.0
Kinsman		0.6	1.0
Avalon	9	10.0	14.0
Rapier		0	0
Virtue		0	0
Hustler		0	0
Moulin		0	0
Ambassador		0	0.1
Corinthian		0	0
Axona*		0	0
Jerico*		0	0
Slejpner		0	0
Brimstone		Tr	0.1(R)
Venturia*		Tr(MS)	Tr(MS)
Broom*		Tr	Tr
Gawain		1.0(MR)	1.0(MR)
Wembley*		4.0	11.0
Solitaire*		4.0	9.0
Boxer		4.0	6.0
Longbow		3.0	2.0
Galahad		4.0	3.0
Fenman		7.0	4.0
Mercia		11.0	4.0
Brock		15.0	12.0
Alexandria*		13.0	13.0
Mission		14.0	12.0
Armada		15.0	13.0
Minaret*		19.0	10.0
Timmo*		20.0	23.0
Renard		25.0	16.0
Musket*		27.0	23.0
Tonic		30.0	26.0
LSD		5.9	6.8

All reaction types susceptible unless indicated
* = Spring cultivars; $\bar{x}$(%) = mean of three assessment dates
MS = Mixed susceptible; MR = Mixed resistant; R = Resistant

BROWN RUST OF WHEAT TESTS AT NIAB

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Ten isolates of Puccinia recondita were used in adult plant and seedling tests of 36 winter wheat cultivars. Specific resistance factors were provisionally identified in some new cultivars and previous identifications were confirmed. Six cultivars were resistant to all isolates at the adult plant stage.

INTRODUCTION

The main aim of the NIAB tests in 1985 was to examine cultivar x isolate interactions, using a wider spectrum of isolates of P. recondita than is normally possible during routine evaluation of cultivars. Specific resistances to brown rust (WBR factors) referred to in this paper are listed in Table 1, together with examples of cultivars possessing each.

Table 1

Resistance factors* to Puccinia recondita and examples of cultivars possessing each

WBR Factor	Gene	Type	Cultivar(s)
WBR 1	Lr 26	O	Clement, Stuart
	?	A	Aquila
WBR 2	?	O/T	Maris Fundin
WBR 5	?	A	Maris Huntsman
WBR 8	?	A	Maris Ranger
WBR 9	?	A	Avalon, Bounty

* includes only those WBR factors referred to in this paper.
O = overall resistance, effective at all growth stages.
A = adult plant resistance, not effective at seedling stage.
T = temperature sensitive.

METHODS

The methods used for seedling and adult plant tests were similar to those described for wheat yellow rust by Priestley, Bayles & Thomas (1984). Ten isolates (Table 2), supplied by WPBS, were tested on seedlings and adult plants of 36 winter wheat cultivars.

Table 2 Isolates used in adult plant tests

Code	Source Cultivar	Site	WBV Factors
74/11	Maris Fundin	Seale Hayne, Devon	2
77/9	Maris Ranger	WPBS, Wales*	1,2,5
77/22	Aquila	North Coates, Lincs	1
80/1	Brigand	WPBS, Wales	1,2,5+x
80/13	Mardler	Romney Marsh, Kent	5
P82/1	Aquila	PBI, Cambridge	2,9
83/19	Brigand	Winchester, Hants	5
83/24	Norman	Winchester, Hants	(2),5
83/27	Longbow	Winchester, Hants	2,9,5
83/65	Longbow	Terrington, Norfolk	2,5

RESULTS

The results of adult plant tests in Polythene tunnels and seedling tests are summarised in Table 3. Boxes in the body of the table have no statistical significance and are used merely for reference.

WBR 1 cultivars: The WBR 1 cultivars Clement, Hammer, Stuart and Stetson were susceptible to isolates in Box A as seedlings and, with a few exceptions, showed evidence of interaction with these same isolates as adult plants. There were however higher than expected levels of infection with some non-WBV 1 isolates, presumably due to contamination in adult plant tests. As usual, Aquila interacted with WBV 1 isolates at the adult plant stage only.

Abele and Baron, in which the WBR 1 resistance is detectable at the seedling stage, interacted specifically with isolate 80/1 as adult plants (Box B). This interaction, noted in previous reports (Priestley & Crofts 1982) has led to the designation of the resistance of those cultivars as WBR 1+x, x being an adult plant resistance.

Three new cultivars, Ambassador, Corinthian and Wand, partially resembled the WBR 1+x cultivars by interacting at the adult plant stage with isolate 80/1 the isolate which gives increased infection on Abele and Baron. However, their patterns of seedling reactions differed from that of Abele and Baron suggesting that their resistance has something in common with the WBR 1+x cultivars, coupled with additional resistances.

Another new cultivar, Slejpner clearly possesses WBR 1 at the seedling stage, combined with adult plant resistance which is currently effective against all isolates.

WBR 2 cultivars: The results indicate some apparent inconsistencies between seedling reactions and adult plant infection levels for the WBR 2 cultivars In particular, isolates 83/24, 83/65 and 83/27, which gave low average infection types on seedlings of M Fundin, Renard and Brock, produced moderate levels of infection on adult plants. This was probably due to slight contamination of isolates by WBV 2.

Adult plants of Maris Fundin interacted with isolates in the Boxes marked C. Renard and Brock showed some similarity to Maris Fundin in their pattern of interactions (Boxes D) and the same isolate (74/11) gave maximum infection on all three cultivars. There is an indication therefore that Renard and Brock possess WBR 2 as part of their resistance complement. This has not been noticed before, since all isolates used in earlier years' tests possessed virulence for WBR 2.

Hobbit and Norman, also classified as WBR 2, showed increased levels of infection with some, but not all, of the isolates producing high levels of infection on Maris Fundin (Box E), confirming the view that these cultivars possess WBR 2 combined with other resistances (Clifford & Jones, 1984).

Maris Bilbo interacted strongly with isolates 83/27 and P82/1 (Box F), which also gave high infection on Avalon (Box H) and therefore possess virulence for the adult plant resistance WBR 9. This confirms the identification of Maris Bilbo's resistance as WBR 2,9 (Bayles & Thomas 1985).

WBR 5 cultivars: Maris Huntsman (WBR 5) was relatively susceptible to isolates in Box G. With a few exceptions, Mardler and Longbow (also WBR 5) followed the same pattern.

Although Galahad and Mercia were generally more resistant than Longbow, Mardler and M Huntsman, there was some evidence that they were more susceptible to WBV 5 isolates than others. This is a preliminary indication that Galahad and Mercia may possess WBR 5.

Other cultivars: Brimstone, Hustler, Moulin, Virtue, Gawain and Rapier remained resistant to all isolates at the adult plant stage.

It should be noted that the cultivar Brigand, as used in these tests, is a brown rust resistant selection from the original cultivar. Brigand used to be highly susceptible, at the adult plant stage, to isolates possessing WBV 5. However, the newly selected stock of the cultivar is resistant to all isolates tested.

Isolates: All the major virulences identified to date were represented in the ten isolates used. Every possible combination of virulence factors was detected with the exception of WBV 1 with WBV 9. Although only a restricted sample of isolates was examined, the indications here and from previous results are that the best option available for varietal diversification, (apart from growing a selection of varieties with complete resistance) would be to grow cultivars from the WBR 1 and WBR 9 groups. Unfortunately, the number of commercial cultivars in these groups is very limited and there are currently no recommendations for varietal diversification for brown rust.

Table 3 Brown Rust of Wheat. Results of adult plant and seedling tests. Values are mean percent leaf area infection (3 assessment dates)

Cultivar	WBR Factors	Isolate	77/22	77/9	80/13	80/1	83/19	83/24	83/65	83/27	P82/1	74/11
		WBV Factors	V1	V1,2,5	V1,2,5	V1,2,5+x	V5	V(2),5	V(2),5	V(2)9,5	V(2)9	V2
Clement	1		27	13	0	6	0	5	3	2	0	4
Hammer	1		4	1	6	6	1	1	0	0	0	0
Stuart	1		23	6	2	6	0	4	0	4	1	1
Stetson	1		13	4	5	8	0	2	0	3	0	0
Aquila	1*		7	3	3	4	0	1	2	0	0	0
Abele	1+x		2	0	1	5	0	3	1	0	0	0
Baron	1+x		7	3	8	12	0	1	1	0	1	0
Ambassador			0	0	1	3	0	0	1	0	0	0
Corinthian			1	0	4	7	0	1	1	1	0	0
Wand			0	0	2	10	0	1	1	0	1	0
Slejpner	1+APR		0	0	0	0	0	0	0	1	0	0
M Fundin	2		3	8	12	8	1	8	6	7	12	16
Renard	2+		2	8	0	3	1	3	12	6	8	20
Brock	2+		0	5	0	4	0	3	4	2	0	5
Hobbit	2+		0	2	1	1	0	1	6	2	0	0
Norman	2+		0	0	5	5	0	0	11	2	0	0
M Bilbo	2+9		0	0	1	2	1	2	1	12	24	6
Longbow	5		2	1	8	5	6	4	8	6	0	0
Mardler	5		1	6	1	12	1	5	16	20	1	0
M Huntsman	5		3	6	5	11	5	11	11	18	4	0
Galahad			0	2	1	0	1	2	3	4	1	0
Mercia			0	3	2	1	2	1	4	3	0	0
Maris Ranger	8		5	2	0	3	0	3	7	1	0	1
Avalon	9		0	1	0	3	0	1	0	6	9	3
Bounty	9		0	0	0	1	0	2	0	5	2	0
Brimstone			0	0	0	0	0	0	0	0	0	0
Hustler			0	0	0	0	0	0	0	0	0	0
Moulin			0	0	0	0	0	0	0	0	0	0
Virtue			0	0	0	0	0	0	0	0	0	0
Brigand**			0	0	0	0	0	0	0	0	0	0
Gawain			0	0	0	0	0	0	0	0	0	0
Rapier			0	0	0	0	0	0	0	1	0	0
Boxer			8	3	6	7	1	6	1	7	0	1
Mission			7	2	7	3	1	3	5	11	6	0
Fenman			10	8	11	5	3	4	13	7	9	4
Armada			13	5	8	7	3	11	9	11	18	8

Underlining = susceptible reaction type (>2.00) in seedling tests.

x = un-numbered WBR factor and corresponding WBV factor

* = expressed at adult plant stage only ** = re-selected from original cultivar Brigand.

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MILDEW OF BARLEY

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The newly introduced resistance genes from cv.Rupee (Mla13, Ru2, Ru3) coded as BMR 10, were confirmed in several spring and one winter cultivar. Pathogenicity for cv. Triumph increased widely. The negative associations of BMV 6 with BMV 4 and with BMV 5 were confirmed in several experiments. The crucial importance of combined pathogenicity on winter and spring cultivars to survival of the pathogen was clearly evident.

High levels of insensitivity to triazoles were more common than previously in eastern England, although triazole insensitivity continued to decline in northern Scotland. There was evidence of a pathogen response to ethirimol, tridemorph and fenpropimorph, although at a low level with the latter two fungicides. These responses occurred in combinations, the most common being combined insensitivity to triadimenol and ethirimol. Despite these trends, fungicide insensitive isolates were less fit than sensitive isolates in the absence of the selective fungicide.

Identification of resistance phenotypes

1. Winter barley: The majority of new cultivars possess BMR 1b (Table 1) alone, for example, cvs. Concert, Plaisant and Sonate. However, resistance genes, and their combinations, from spring cultivars are becoming increasingly common, for example, in cvs. Kaskade (BMR 5), Marinka and Natalie (BMR 2,6b). With help from H P Jensen (Risø) we confirmed that cv. Pipkin has the spring resistance genes BMR 4,10 (Mlv,Mla13). Fortunately, there is no evidence so far of winter barley cultivars with BMR 9 (mlo). Development of such cultivars should be strongly discouraged since they would greatly promote survival of pathogen clones adapted to BMR 9.

2. Spring barley: Among the spring cultivars, there were several new entries which probably possess BMR 9, including cv. Dandy. The collaboration with H P Jensen helped to show that cvs. Clansman, Digger and Sherpa may each have some combination of the resistance genes in BMR 10 (Mla13, Ru2, Ru3). A number of new spring cultivars have resistance which is so far unidentified, for example, cv. Camargue, but others derived from cv. Magnum, for example, cvs. Ayr and Esk, may have BMR 4,8,? The new combination identified in 1984, BMR 5,6c (cvs Acclaim and Natasha), has been found in cvs. Blenheim, Corniche and possibly cv. Kingpin and others. The related combination, BMR 4,6c, occurs in cv. Everest. More cultivars with BMR 7 have been identified, including cv. Flute (BMR 2,7) and cv. Regatta (BMR 4,6a,7). Cv. Tennis appears to be similar to cv. Klaxon (BMR 4,6ab). The resistances of most of these latter cultivars, and others such as cv. Auto (BMR 3,4,6a), is unlikely to be durable in monoculture because they are matched by combinations of pathogenicity genes which already exist in the pathogen population.

Pathogen population structure

Changes in frequency of the major pathogenicity characters in recent years are shown in Table 2. They are characterised by the increase in pathogenicity for cv. Triumph (BMR 6bc, where 6b = Mla7, 6c = MlAb: Table 1). The negative association of BMV 6 with BMV 4 and with 5, which has been observed for many years, has led to a general decrease in frequency

Table 1. Barley cultivars used as the main differentials of pathogen isolates

BMR gp	Cultivar	BMR gp	Cultivar	BMR gp	Cultivar
0	Gold. Prom.	6a (Mlk)	H. 1063	10*	Sherpa
1a	W. 37/136	6b (Mla7)	Porter	4,6b	Doublet
1b	W. 41/145	6ab	Ark Royal	4,6ab	Klaxon
2 (Mlg)	Julia	6bc(Mla7,Ab)	Triumph	4,7	Vista
3 (Mla6)	Midas	7 (Mla1)	Delta	4,8	Kym
4 (Mlv)	Lofa	8 (Mla9)	Simon	5,6c	Natasha
5 (Mla12)	Hassan	9 (mlo)	Apex		

*complex, involving a combination of Mla13, Ru2 and Ru3

of the latter two characters (see also Tables 3-6). BMV 3 increased rapidly in 1982 and 1983, associated with the increased frequency of BMV 6bc and triazole insensitivity, but it now appears to be declining.

Table 2. Changes in frequency of the major pathogenicity characters since 1978, determined from general survey samples

	BMV character				
Year	2	3	4	5	6bc
1978	72	22	9	22	
1979	60	23	12	28	
1980	71	26	17	27	
1981	74	22	26	25	
1982	48	43	28	23	(6)
1983	(63)	(49)	(35)	(30)	(22)
1984	64	42	22	17	22
1985	39	40	15	14	32

() NIAB trials samples

Evidence for the negative association of BMV 6bc with BMV 4 and with BMV 5, was observed during 1985 from analyses of the isolates obtained from untreated seedlings of cv. Golden Promise exposed on a roof in Cambridge (Table 3). Although cv. Triumph possesses only BMR 6bc, pathogen populations on this cultivar have always contained high frequencies of BMV 6a (Mlk), because previous cultivars mostly carried BMR 6ab.

Table 3. Changes in frequency of pathogenicity during 1985 estimated from isolates obtained from a roof and tested in the laboratory

	BMV character			
Month	4	5	6a	6bc
March	41	26	35	42
April	34	18	41	49
May	20	18	52	55
June	21	14	50	44
July	9	7	56	69

Further evidence for the negative association of BMV 6 with BMV 4 and with BMV 5 was established from laboratory tests of isolates obtained from the

roof on seedlings of differential cultivars (Table 4). From Table 4, the frequencies of BMV 4 and 5 on cultivars with BMR 6a or 6bc were very low; conversely, the values for BMV 6a and 6bc were very low on cultivars with BMR 4 or 5.

It is important to note that all BMV characters were relatively common on the winter barley differentials (BMR 1a, 1b), indicating the importance of winter survival for the genotypes involved. This was particularly evident for BMV 6bc (pathogenicity for cv. Triumph); conversely, BMV 1a and 1b were common in the samples from cv. Triumph. On the other hand, BMV 1a occurred at a relatively low frequency in the samples from BMR 3, 4 and 5. Presumably, this reflects the decreased popularity of winter cultivars with BMR 1a, so that BMV 1a is less important for winter survival. Other evidence (not shown) suggests that the BMV characters selected on spring cultivars tend to decline on winter cultivars during the winter. During the late spring and summer, however, they increase again on winter cultivars, presumably due to migration.

Table 4 Pathogenicity profiles of isolates trapped on differential cultivars exposed on a roof in Cambridge

	BMV character						
Source	1a	1b	3	4	5	6a	6bc
BMR 1a	70*	60	50	28	21	52	53
1b	29	53*	48	53	31	30	38
3	25	48	67*	85	17	44	19
4	1	30	70	92*	7	0	1
5	5	26	50	48	25*	0	0
6a	44	8	66	7	5	74*	52
6bc	58	39	52	0	0	86	72*

Similar evidence for the negative associations between pathogenicity characters, and for the distribution of BMV 1a and 1b, was obtained from analyses of the pathogen populations on leaf samples from trials at NIAB Headquarters (Table 5). The BMV 6 genes and BMV 1a were much less frequent in samples from cvs. Delta, Vista and Patty than in those from cv. Triumph or a group of BMR 1b cultivars. In the samples from cvs. Corniche, Natasha and Acclaim, the BMV 6 genes occurred at a higher frequency, despite the fact that the hosts possess BMR 5. This apparent deviation from the expected negative association occurs because the three cultivars also select for BMV 6c, which has the effect of maintaining the frequency of BMV 6a and 6b because of the strong association of these three characters in the large populations generated on cv. Triumph. Nevertheless, it is clear from Table 5 that the complex of pathogenicity genes generated from cv. Triumph is being broken on cvs. such as Corniche, Natasha and Acclaim, because the esimated frequency of BMV 6c was much higher than that of BMV 6a or 6b on these cultivars.

From Table 5, BMV 1b was maintained at high frequency on all cultivars. This underlines the paramount value of introducing strong diversification between winter and spring crops, not only for host resistance, but also in fungicide use. Unfortunately, plant breeders and fungicide companies are proceeding in the opposite direction, introducing 'spring' resistance genes into winter cultivars, and recommending the use of the same fungicides on winter and spring crops.

In population samples from cv. Natasha (Table 6), the only BMV characters

Table 5. Pathogenicity of mildew populations on spring cultivars relative to that on winter cultivars, from leaf samples at NIAB, Cambridge

Source	BMV character 1a	1b	4	5	6a	6b	6bc
BMR 1b	30	23	27	28	42	31	39
Delta	1	58	56	12	0	15	1
Vista	18	34	43*	24	1	13	1
Patty	17	59	62	81*	4	2	3
Corniche	63	86	42	81*	0	23	34
Natasha	20	38	40	54*	24	27	17
Acclaim	4	54	11	73*	35	32	20
Triumph	70	77	0	1	79	72*	71

that consistently increased were those under selection, BMV 5 and 6c. The increasing frequencies of BMV 6b and 6bc were probably due to immigration of spores with pathogenicity for cv. Triumph.

Cultivars Delta and Vista possess BMR 7 but the latter also has BMR 4. This difference may be responsible for the differential interaction of isolates from these cultivars on test seedlings of cvs. Delta (BMV 7) and Vista (BMV 4,7). In a similar way, the cultivars Doublet and Klaxon differ only slightly in their resistance characters, but there is a considerable difference in the adaptation of the pathogen populations from each to growth on BMR 6a, 6b and cv. Doublet itself (BMR 4,6b). These differences are sufficient to suggest that mixtures of cvs. Doublet and Klaxon, or of cvs Delta and Vista, would generate significantly less disease than the mean of the cultivars grown pure.

Table 6. Pathogenicity on cv. Natasha and comparisons between pairs of related cultivars, from stick samples from the field

Source	BMV character 1a	1b	2	3	4	5	6a	6b	6bc	5,6c	7	4,7	8	4,6b
Natasha														
16/5	16	19	5	0	0	11*	31	16	5	78*	0	0	0	0
13/6	26	5	14	25	1	26*	3	41	23	79*	0	0	0	0
27/6	37	25	33	18	7	30*	20	52	42	84*	1	0	0	1
23/7	17	14	9	3	0	30*	16	47	38	100*	0	0	0	0
Delta	17	29	54	35	55	14	42	19	1	13	74*	65*	0	1
Vista	1	14	42	38	45*	13	0	20	0	8	49*	84*	0	3
Doublet	45	56	65	29	70*	28	50	90*	21	20	0	0	22	61*
Klaxon	15	26	38	25	62*	7	52*	62	0	2	0	0	36	24

* corresponding pathogenicity

Pathogen response to fungicides

In 1985, there was a considerable change in the response of the pathogen population to triazole fungicides in eastern England (Table 7). Isolates

insensitive to seedling leaves grown from seed treated with the field rate of triadimenol became much more common than previously, indicated by high scores at the highest dose (Table 7). Curiously, there was an apparent decline in insensitivity at the lowest dose. One explanation may be that isolates with intermediate insensitivity grow better at low rates of fungicide treatment than do those with high levels of insensitivity; this would be reflected in the frequency data since the latter were obtained from bulk isolates rather than from single colonies.

Table 7. Insensitivity to triazole fungicides in eastern England measured directly (relative colony counts on treated seedlings exposed in the WIST), or indirectly in the laboratory from samples obtained from untreated seedlings of cv.Golden Promise exposed on high roofs in Cambridge (July only for each year)

Seed trt.	1981	1982	1983	1984	1985
a)Direct (WIST)					
0.025 g a.i.	23	51	83	85	64
0.075 g a.i.	-	27	54	54	70
0.125 g a.i.	-	-	-	24	43
b)Indirect (Roof)					
0.025 g a.i.	-	-	118	138	78
0.075 g a.i.	-	-	24	56	76
0.125 g a.i.	-	-	11	21	74

Mean pathogenicity and fungicide insensitivity for May, June and July were calculated from samples obtained from untreated seedlings of cv. Golden Promise exposed on high roofs in Bristol or Cambridge or in the WIST in the Cambridge-Essex area (Table 8). The pathogenicity profiles for all three areas were dominated by the high frequency of pathogenicity for cv. Triumph (see also Tables 2-6). Insensitivity to triadimenol was also high (0.375 g a.i. is the field rate) and generally distributed, although insensitivity was higher in the east than in the west.

Table 8. Mean pathogenicity and fungicide insensitivity profiles for May, June and July in pathogen isolates trapped on high roofs in Bristol and Cambridge and in the WIST in Essex and Cambs.

	BMV character								g ai triad.	
Source	1a	1b	2	3	4	5	6a	6bc	0.025	0.375
Bristol	66	60	51	39	8	14	59	51	87	38
Cambridge	53	42	41	57	17	13	53	56	88	58
WIST	60	48	42	41	11	9	53	50	61	75

Among the pathogen populations trapped on untreated seedlings over larger areas (Table 9), pathogenicity for cv. Triumph dominated the population from the south-west (SW), through eastern England (Esx) and north from the east Midlands to Durham (EM & D.). This distribution was associated with relatively low frequencies of BMV 4 and 5. In the north of England and Scotland, however, the population was distinct, due to the lesser popularity of cv. Triumph. The frequencies of BMV 6a and 6bc were noticeably lower, and those of BMV 4 and 5 noticeably higher, than further south. In the north and the south-west, the triazole-selected populations had a considerably lower frequency of BMV 1a, presumably because BMR 1a

has been little used in these areas in recent years. BMV 6a and 6bc were also uncommon in the triazole insensitive populations in these areas, presumably because cv. Triumph was still resistant and not treated intensively with fungicide, so that it did not select so strongly for fungicide insensitivity.

Table 9. Variation in distribution between four areas of the major pathogenicity characters in whole populations and in triadimenol insensitive populations (WIST data)

Source	BMV character 1a		1b		3		4		5		6a		6bc	
	u	t	u	t	u	t	u	t	u	t	u	t	u	t
N.& Sc.	43	15	54	49	41	44	39	47	30	26	17	4	14	5
EM & D.	34	31	38	39	43	33	28	21	24	19	42	39	38	34
Esx	60	50	48	48	41	42	11	11	9	9	53	58	50	55
SW	40	4	45	25	45	33	27	55	23	5	69	16	57	6

u = untreated seedlings; t = seedlings treated with 0.125 g ai triadimenol per kg seed

Triazole insensitivity increased considerably in eastern England from 1984 to 1985, but this pattern was not repeated generally (Table 10). In northern England and the Borders, there was little change between the two years, although there was a deterioration in eastern Scotland. In northern Scotland, the pathogen population has become progressively more sensitive to triazoles since 1983, probably due to greater diversification of fungicide use. In contrast, there appears to have been a widespread decrease in the sensitivity of the pathogen population to ethirimol.

Table 10. Variation in different years over six areas of pathogen insensitivity to triadimenol and to ethirimol (WIST data).

Area	triadimenol trt. 1/5 field rate 1984	1985	1/3 field rate 1984	1985	ethirimol trt. 1/5 field rate 1982	1985
N Scot.	45	21	12	11	6	15
E Scot.	77	57	16	28	5	12
Lothians	47	61	22	17	4	25
N. Engl.	-	51	35	27	2	3
E. Mids.	152	102	80	60	2	17
E. Angl.	54	70	24	43	-	16

The pathogen population was sampled from different areas to determine the occurrence and distribution of the response to the most widely used mildew fungicides (Table 11). Isolates sensitive to triadimenol or ethirimol are completely controlled by 1/15 of the respective field rates over a wide range of environmental conditions. This clear difference between sensitive isolates and the rest provides the basis for surveys of distribution. Response to tridemorph and fenpropimorph has been much more difficult to determine because of variation between tests and the difficulty of establishing a base-line for sensitivity. Nevertheless, from comparisons with standard isolates, there was evidence of a pathogen response to tridemorph and to fenpropimorph, although both responses were at a low level. The effects are more obvious in Table 12 than in Table 11.

Insensitivity to triadimenol was widespread at a high level; ethirimol insensitivity at a lower level was also widespread, but appeared to be particularly common in eastern and northern Scotland (Table 11).

Table 11. Relative pathogen colony number on leaves treated with different fungicides using isolates from untreated seedlingsd in the WIST.

	Fungicide and dose as fraction of field rate				
Source	triadim. 1/3	ethirim. 1/15	tridemor. 1/20	fenprop. 1/100	prop./trid. 1/15
N. Scot.	70	43	49	4	47
Borders	59	21	45	5	40
E. Engl.	67	25	43	27	52
W. & SW.	64	14	51	26	22

For Table 12, the tests were as in Table 11 except that the population samples were obtained from WIST seedlings treated either with triadimenol (1/5 field rate) or ethirimol (1/15 or 1/5 field rate, data combined). Triadimenol insensitivity was highest in the populations from triadimenol-treated seedlings, but was equally high in those from ethirimol-treated seedlings exposed in eastern England and as far north as the Borders. Thus, in these areas, combined insensivity to both fungicides must have been relatively common. This was confirmed in the population samples obtained from ethirimol treated seedlings, which provided the highest levels of ethirimol insensitivity, but high levels were also recorded from triadimenol treated seedlings, particularly from those exposed in the north of Scotland.

Relatively high levels of tridemorph insensitivity were recorded from both sorts of exposed seedlings (Table 12), and these were generally higher than the levels on untreated exposed seedlings (Table 11). Thus the response to tridemorph is associated with both triadimenol and ethirimol insensitivity. The association between tridemorph and ethirimol insensitivity appears stronger than that for tridemorph and triadimenol. This difference could be due to the history of fungicide usage in that there was selection for combined insensitivity to ethirimol and tridemorph during the 1970's.

Table 12 Relative pathogen colony number on leaves treated with different fungicides using populations obtained from different areas on WIST seedlings treated either with triadimenol or ethirimol.

	Test fungicide (doses as in Table 11)									
	triadim.		ethirim.		tridemor.		fenprop.		prop./trid.	
trap:	tr	et	tr	et	tr	et	tr	et	tr	et
N. Scot.	83	40	32	42	49	76	31	8	35	38
Borders	92	86	14	51	55	47	33	21	45	38
E. Engl.	85	88	24	62	52	62	22	23	37	40
W. & SW.	76	36	10	27	70	85	35	-	40	41
means	84	63	20	46	57	68	30	17	39	39

Reduced sensitivity to fenpropimorph was more evident in the samples from triadimenol treated seedlings than in those from ethirimol treated or untreated seedlings indicating an association with triadimenol

insensitivity. The response to the mixture of propiconazole and tridemorph was also small, and, from the original data, was correlated with the response to tridemorph.

Increased use of homogeneous mixtures of fungicides will select for the combinations of fungicide insensitivity which now appear to be detectable, in the same way as has often occurred with combinations of resistance genes. One indication came from an experiment with 1141 single colony isolates obtained from fields near Cambridge either not treated or treated with triadimenol. The isolates were classified as being moderately or highly insensitivite to triadimenol, and sensitive or moderately insensitive to ethirimol and were expected to be randomly distributed between the four classes. However, irrespective of their origin, significantly more isolates than expected had high insensitivity to triadimenol combined with reduced sensitivity to ethirimol ($P<0.001$).

Data obtained from tests of single colonies by J K M Brown from the seedlings exposed on a Cambridge roof confirmed the association of insensitivity to triadimenol and ethirimol and identified the pathogenicity phenotype of common isolates (Table 13). Not surprisingly, insensitivity to both fungicides was closely associated with pathogenicity for cv. Triumph (BMV 6bc), because of the intensive treatment of the large area of cv. Triumph which is now susceptible. Interestingly, the close association of characters was not evident among those isolates with BMV 3 in addition to BMV 6bc. The explanation may be that the latter clones represent the linkage disequilibrium noted in the previous two years when it was suggested that the unexpected association of BMV3 with moderate insensitivity to triadimenol arose because of migration of those phenotypes into eastern England from the south of Scotland.

Table 13 Distribution of reduced sensitivity to ethirimol among single colony isolates pathogenic to cv.Triumph, with or without BMV 3, and with different sensitivities to triadimenol (Roof isolates).

	BMV 3,6bc			BMV 6bc		
triad. insens.:	low	med.	high	low	med.	high
ethir. sens.	0	10	11	1	0	0
ethir. insens.	0	2	3	0	0	9

Analyses were also made of single colonies from fields of cv. Triumph treated either with triadimenol or a mixture of flutriafol and ethirimol, near Cambridge. The latter yielded isolates almost all of which were pathogenic to cv. Triumph, highly insensitive to triadimenol, and moderately insensitive to ethirimol. This phenotype was less common in areas treated with triadimenol alone, except where such areas were close to fields treated with the fungicide mixture.

Despite the trend to increased insensitivity to triadimenol, other field experiments showed that insensitive isolates were still less competitive than sensitive in the absence of triazoles. Furthermore, adjacent plants treated either with a triazole or ethirimol alone discouraged the spread of combined insensitivity compared with plants treated with the fungicide mixture.

MILDEW OF BARLEY IN NORTHERN IRELAND

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The growing season in 1985 was one of the wettest for many years and the incidence of mildew was low, judging from the number of advisory queries, down 75% from the previous year. 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
6ab	Keg
6bc	Triumph
7	Delta
8	Leith
3+4	Goldspear
4+5	Egmont
4+6a	Dram

Table 2 shows values for the mean pathogenicity of isolates taken from leaf samples from 23 crops and tested as in 1984. Table 3 shows a comparison of non-corresponding pathogenicity values in Northern Ireland for the last three years with those obtained in England over the same period (Wolfe et al, 1984; 1985; 1986).

The data were more variable than in 1984, with unexplained low figures for mean pathogenicity for group 2 virulence with Golden Promise and Camelot isolates. Only one isolate was obtained from Camelot but it did not confirm the assignment of this cultivar to BMR group 8.

TABLE 3 Comparison of non-corresponding pathogenicity values in Northern Ireland and England, 1983-85

		BMV characters							
Location	Year	2	3	4	5	6ab	6bc	3+4	4+5
N. Ireland	1983	59	53	59	37	16	22	45	32
N. Ireland	1984	48	45	42	40	17	24	29	38
N. Ireland	1985	65	54	60	69	31	37	35	34
England	1983	63	49	35	30	17	22	11	14
England	1984	64	42	22	17	24	22	6	6
England	1985	39	40	15	14	30	32	14	11
Scotland	1983	49	57	27	33	14	13	8	3
Scotland	1984	69	54	24	27	39	19	26	7
Scotland	1985	-	41	39	30	17	14	-	-

TABLE 2 Mean pathogenicity of bulk isolates in 1985 on test range of cultivars

BMR group	Isolate source	No	BMV characters										
			2	3	4	5	6ab	7	8	3+4	4+5	4+6a	6+bc
0	Golden Promise	2	14	65	75	52	15	0	2	16	4	8	41
1	Igri	5	68	50	56	64	36	1	13	27	19	4	36
3	Midas	1	141	76	31	95	14	0	0	58	65	0	20
7	Delta	1	114	83	48	58	40	96	0	32	55	0	0
?8	Camelot	1	21	2	96	59	52	0	0?	29	0	15	65
2+4	Golf	2	31	41	42	81	23	0	23	20	42	23	42
2+5	Patty	1	107	35	70	71	35	0	9	38	119	26	38
3+4	Goldmarker	3	70	46	50	80	15	0	17	21	50	15	29
4+bc	Everest	1	50	79	112	99	51	0	28	92	47	43	72
4+5	Egmont	1	97	71	38	97	4	0	7	91	138	0	16
4+8	Cameo	1	30	45	82	85	79	15	68	41	46	36	75
5+bc	Natasha	1	103	104	126	97	35	0	28	62	51	54	26
6+bc	Triumph	3	52	47	35	50	67	0	2	16	6	65	70

Average figures for non-corresponding pathogenicity were higher than in 1984. Those for groups 2, 3, 4 and 3+4 were more similar to 1983. For groups 5, 6ab and 6bc they were higher than either 1983 or 1984, while for 4+5 they remained fairly consistent over the three years. Values for groups 4, 5, 3+4 and 4+5 were all, as in previous years, higher than comparable figures for England or Scotland. Those for 6ab and 6bc were comparable with English figures, showing a substantial rise over the previous years. Scottish figures for these groups were, on average, lower, possibly due to cv. Triumph being less popular in this area.

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YELLOW RUST OF BARLEY

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Only one sample of yellow rust of barley was received. A number of isolates previously classified as possessing virulence for Triumph were included in seedling and adult plant tests of spring barley cultivars. In contrast to earlier years' experience, none gave high levels of infection on adult plants of Triumph or related cultivars and seedling reactions were variable. These results indicate inconsistency of cultivar x isolate interactions involving the BYR 3 resistance.

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	0	Astrix, Atem	1960
BYR 2	0	Bigo Varunda	)1972-1975
	S	Mazurka	)
BYR 3	?S	Triumph	1983

*0 = 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).

1985 Survey

Only one sample was received in 1985 and this failed to establish. This lack of samples was entirely consistent with the extremely low incidence of yellow rust of barley in variety trials during the season.

Isolates from previous years

Tests were carried out to provide further information on the increased virulence of certain isolates for the cultivar Triumph and the relationship between virulence for seedlings and adult plants of Triumph. The five test isolates listed in Table 2 included one known to be avirulent on Triumph at all growth stages, (75/101), three which had previously given increased levels of infection on Triumph in Polythene tunnel tests (80/47, 80/80 and 83/38) and a new isolate from the 1984 survey which had been virulent on seedlings of Triumph when first tested (84/2). All isolates were tested on 24 spring barley cultivars in seedling tests and adult plant Polythene tunnel tests and three of the isolates were also tested in comparable adult plant tests in field spreader beds.

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

Code	Source cultivar	Site	BYV Factors
75/101	Varunda	Boroughbridge, Yorks	1,2
80/47	Erna	Berwick, Scotland	1
80/80	Dragon	Seale-Hayne, Devon	1,3,*
83/38	Triumph	Farndon, Cheshire	1,3,**
84/2	Klaxon	Cockle Park, Northumberland	1,2,***

* originally BYV 1
** originally BYV 1,2,3
*** originally BYV 1,2,3

RESULTS

The results are summarised in Table 3. Two isolates, 80/80 and 83/38, were virulent on seedlings of Triumph, but not on all other cultivars in the BYR 3 group proposed last year (Bayles and Thomas, 1985). The virulence of 84/2 for Triumph was not confirmed.

In contrast to the previous years' results, no isolates gave high levels of infection on adult plants of Triumph.

The interaction between cultivars of the Triumph type and isolates of P.striiformis seems to be particularly inconsistent. We had suspected in the past that the resistance of Triumph might have been less effective in higher temperatures experienced in Polythene tunnels than under normal field conditions, but there was no evidence here to substantiate this. The fact that early summer temperatures were unusually low in the Polythene tunnels in 1985 may possibly have influenced the results. Clearly, in some circumstances, adult plants of Triumph and other BYR 3 cultivars can become heavily infected with yellow rust. However, it is difficult to define critical conditions or to relate adult plant infection levels to specific cultivar x isolate interactions detected at the seedling stage.

The six cultivars listed from Corniche to Golden Promise in Table 3 are a heterogeneous group with variable seedling reactions. Amongst these cultivars there are clear examples of resistance at the seedling stage being followed by

susceptibility at adult plant stages. This phenomenon, which also occurs within the Triumph group of cultivars, appears to be fairly common in yellow rust of barley, but has not been detected in yellow rust of wheat.

REFERENCE

Priestley, R H, Bayles, R A and Thomas, J E (1984). Identification of specific resistance against Puccinia striiformis (Yellow Rust) in winter wheat varieties 1. Establishment of a set of type varieties for adult plant tests. Journal of the National Institute of Agricultural Botany, 16, 469-476.

Table 3 Yellow Rust of Barley Adult Plant Tests 1985

Percent leaf area infection (mean of 3 assessments)

	Isolate	80/47	80/80		83/38		75/101		84/2
	BYV Factors	1	1,3		1,3		1,2		1,2
	Polythene tunnel/Field (P) (F)	P	P	F	P	F	P	F	P
Cultivar	BYR Factor								
Apex	1	3	2	5	4	8	1	3	3
Atem	1	17	11	5	5	6	1	1	11
Bigo	2	0	0	0	0	1	0	4	2
Varunda	2	3	3	1	4	1	6	2	11
Mazurka	2	13	6	5	12	9	18	16	29
Triumph	3	1	1	2	1	1	0	0	2
Tasman		0	0	0	0	0	6	0	1
Acclaim		1	1	0	1	1	4	0	4
Carnival		0	0	1	7	1	0	0	2
Doublet		1	0	0	2	5	0	1	2
Natasha		5	3	1	3	2	3	4	9
Corniche		1	0	0	1	2	3	1	1
Patty		2	1	0	0	0	0	1	2
Sherpa		1	1	2	3	11	2	4	5
Vista		12	10	5	5	5	7	3	17
Flute		7	3	2	13	8	9	2	16
Golden Promise		20	6	6	5	2	10	4	27
Cameo		25	11	12	11	9	14	10	21
Golf		23	14	15	11	10	14	11	19
Delta		21	13	11	13	11	15	9	24
Klaxon		32	24	14	10	12	17	13	22
Digger		25	15	13	12	11	17	14	25
Regatta		24	25	9	15	10	14	9	24
Kym		29	19	15	12	13	15	10	33

( ) = partial virulence

__ underlining indicates susceptible reaction type (>2.0) in comparative seedling tests. All other cultivar x isolate combinations gave resistant reaction types.

BROWN RUST OF BARLEY

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Isolates of Puccinia hordei Otth. were successfully cultured and tested from 26 of the 68 samples received in 1985. Four virulence patterns were identified with virulence to cv. Triumph being carried by all but two of the isolates. Tests of adult plants with selected pathogen isolates were carried out in field isolation nurseries. Cv. Medallion was the only winter barley to express resistance to octal race 1673, although quantitative differences in levels of infection were apparent between the other winter cultivars. Comparisons between nurseries inoculated with the three different isolates allowed identification of specific resistances within the spring cultivars. The resistance of cv. Vada remains effective and stable.

GLASSHOUSE SEEDLING TESTS WITH 1985 ISOLATES

Sixty-eight samples of barley brown rust were received of which fifty-three were from winter cultivars sampled from 3 trial sites in the east of England. Also included in the seedling tests were two isolates of Puccinia hordei derived from aecia on naturally infected alternate host species, Ornithogalum nutans and O.umbellatum, received from Long Ashton Research Station. The 26 isolates successfully cultured were tested on the standard set of nine differential cultivars (Table 1). These carry different identified Pa genes for reaction to P.hordei (Jones & Clifford, 1980). In addition, cv. Triumph was included in all tests.

Table 1. Barley genotypes used to identify virulence factors in Puccinia hordei and their ranking for octal notation

Genotype	BBR factor	Gene symbol	Ranking for octal notation
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

Results

The tests identified virulence combinations based on the reactions with the standard differential cultivars. The designations of each octal race identified are given in Table 2. Cv. Triumph has been included in the system of nomenclature as it appears to have a resistance gene not present in the previous set of nine cultivars.

Table 2. Races identified from 1984 isolates

Number of isolates	Octal designation	BRV factors
15	1673	1,2,4,5,6,8,9,10
8	1653	1,2,4,6,8,9,10
2	673	1,2,4,5,6,8,9
1	1253	1,2,4,6,8,10

One isolate, BRS-85-45, sampled from cv. Maris Otter in Terrington was avirulent on the differential cv. C.I. 1243 (BBR-9). All isolates tested in recent years have been virulent on this cultivar. Isolates carrying virulence to cv. Triumph again appeared to give a more resistant reaction on cv. Quinn (BBR-5).

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Winter and spring barley cultivars were sown in each of two isolation nurseries in 1984-1985. In the spring of 1985 a third nursery was sown with spring barley cultivars only. The nurseries were inoculated with one of the three following isolates of P.hordei.

1. Octal race 1673 BRV-1,2,4,5,6,8,9,10
2. Octal race 677 BRV-1,2,3,4,5,6,8,9
3. Octal race 11 BRV-1,4

Octal race 11 was introduced into the nursery sown with spring cultivars only, as previous results had shown that the winter barley cultivars were all resistant to this simple race.

Results

Reasonable levels of infection developed to allow comparisons to be made between cultivars and between isolates (Table 3a and 3b). Levels of infection were generally higher in the winter barley nursery inoculated with isolate octal race 1673. Within the nursery inoculated with this cv. Triumph - virulent isolate, a range of quantitative responses was observed from the highly susceptible cv. Gerbel to the completely resistant cv. Medallion. The quantitative range of responses between winter cultivars inoculated with octal race 677 was not as large.

Specific interactions between isolate and cultivar allowed the spring barley cultivars tested in the isolation nurseries to be placed into groups. One such group included those cultivars with the Triumph resistance (BBR-10), these cultivars being susceptible to octal race 1673 but resistant to the other two isolates. Octal race 677 overcame the specific resistance of cv. Simon (BBR-3). Cv. Corniche was resistant to all three isolates.

REFERENCES

JONES, E.R.L. & CLIFFORD, B.C. (1980). Brown rust of barley. UK Cereal Pathogen Virulence Survey 1979 Annual Report, pp. 55-59.

Table 3a. Barley Brown Rust Isolation Nurseries - WPBS 1985

Winter cultivar	Isolate: Octal race 1673 %	Isolate: Octal race 677 %
Gerbel	18	7
Flamenco	16	4
Natalie	15	8
Vixen	14	3
Marinka	14	7
Sonja	13	5
Igri	12	6
Concert	11	3
Halcyon	11	3
Pirate	10	7
Tipper	10	6
Magie	8	7
Kaskade	8	7
Metro	8	3
Nevada	8	2
Sonate	8	5
Impact	7	4
Opera	7	1
Pipkin	6	5
Otter	6	4
Iceni	6	3
Libra	5	2
Panda	4	3
Monix	2	1
Medallion	0	1MS
LSD	4.5	3.2

% = $\bar{x}$ of 4 replicates at 2 assessment dates
All reaction types susceptible unless stated. MS = Mixed susceptible

Table 3b. Barley Brown Rust Isolation Nurseries - WPBS 1985

Spring cultivar	Isolates: Octal race 1673 %	Octal race 1673 R.T.	Octal race 677 %	Octal race 677 R.T.	Octal race 11 %	Octal race 11 R.T.
Golden Promise	32	S	26	S	24	S
Midas	30	S	21	S	23	S
Acclaim	26	S	1	MR	Trace	MR
Sherpa	24	S	2	MR	0.5	MR
Natasha	24	S	1	MR	Trace	MR
Triumph	21	S	2	MR	0.5	MR
Doublet	21	S	0.5	MR	0.5	MR
Flute	10	S	1	MR	Trace	MR
Klaxon	9	S	7	MS	4	R
Vista	8	MS	4	MS	3	R
Patty	5	MS	7	MS	7	MR
Armelle	11	S	10	S	2	R
Regetta	13	S	8	S	2	R
Delta	13	S	8	S	4	MR
Simon	Trace	MR	16	S	Trace	MR
Corniche	1	MR	1	R	Trace	R
Atem	16	S	16	S	8	S
Golf	8	S	8	S	12	S
Cameo	8	MS	10	S	8	S
Apex	6	MS	12	S	8	S
Digger	13	S	12	MS	8	MS
Vada	4	MS	5	MS	10	MS
Kym	7	MS	11	MS	10	MS
LSD	3.9		2.9		2.5	

% = $\bar{x}$ of 4 replicates at 2 assessment dates

RT = Reaction type; S = Susceptible; R = Resistant;

MS = Mixed susceptible; MR = Mixed resistant

RHYNCHOSPORIUM OF BARLEY

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Seedling tests of 59 Rhynchosporium secalis isolates allowed identification of pathogen virulence factors. Several new virulence combinations were identified together with one new virulence factor, BRV-6. This is the first time that virulence to BRR-6, carried by cv. Osiris, has been detected in the UK. The isolate carrying this virulence factor was also virulent on the remainder of the differential cultivars excepting cv. Pirate (BRR-7). The winter barley cvs Gerbel and Hoppel remained relatively resistant to all isolates tested. High levels of natural inoculum within the three isolation nurseries rendered isolate: cultivar interactions impossible to interprete. Quantitative differences in levels of infection on cultivars within the nurseries were apparent. The spring barley cvs Osiris and MMG 7456/24/1 were resistant.

SEEDLING TESTS WITH 1985 ISOLATES

A total of 149 samples of barley leaf blotch was received reflecting the generally high incidence of the disease in 1985. The majority, 98, were from five trial sites in England and Wales. The geographic origin of the infected leaf samples received is given in Table 1.

Table 1. Geographic origin of Rhynchosporium samples received in 1985

Geographic origin (ADAS region)	Number of samples
East	72
Wales	29
West Central	18
East Central	17
North	7
Eire	6
Total	149

Fifty-two samples were from a wide range of winter cultivars and 96 from spring cultivars, together with one from an unknown cultivar. Fifty-nine isolates of Rhynchosporium secalis were successfully cultured and tested on the standard set of differential cultivars and additional winter cultivars. Test cultivars and their resistance factors are given in Table 2.

Table 2. Differential test-cultivars for Rhynchosporium secalis

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

Results

A range of different virulence combinations was detected in the isolates of R. secalis successfully cultured. The virulence combinations identified have been designated octal virulence numbers (Jones & Clifford, 1984) (Table 3).

Table 3. Virulence factor combinations identified from the 1985 survey

No. of isolates	Differential cultivars in fixed linear order							Octal virulence designation
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
25	0	0	0	0	0	0	0	0
10	0	0	0	1	0	0	0	10
2	1	0	0	1	0	0	0	110
1	1	0	0	0	0	0	0	100
3	0	0	0	1	1	1	1	17
7	1	0	0	1	1	1	1	117
2	0	0	0	0	1	0	0	4
3	0	0	0	1	1	0	0	14
1	1	0	0	1	1	0	0	114
2	0	0	0	1	1	0	1	15
1	1	0	0	1	1	0	1	115
1	0	0	0	0	1	1	0	6
1	0	1	1	1	1	1	1	77

Several new virulence combinations (races) were identified, but they are of little agricultural significance since they only carry previously detected virulences in different combinations. Also, since resistance is being assessed quantitatively, the classification of isolates into races or octal virulence groups is subjective.

One isolate, Rs-85-50, cultured from a leaf sample of cv. Tipper from Spalding, Lincolnshire, carries virulence to cv. Osiris (BRR-6) which has previously been undetected in the United Kingdom. This isolate, which has been designated the octal virulence number 77, is also virulent on all the differential cultivars except for cv. Pirate which showed low levels of infection. Cvs Gerbel and Hoppel were also both relatively resistant to this isolate as they were to all the other isolates tested, but cv. Tipper from which the isolate was cultured was susceptible. Virulence to the winter barley cv. Pipkin was only carried by isolate Rs-85-50 which overcomes the resistance of the Rh^4 gene present in cv. La Mesita.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Three nurseries comprising 28 winter and 25 spring cultivars were sown in the 1984-85 season using standard procedures. The nurseries were each inoculated with one of the following isolates.

Table 4. Isolates used in field tests in 1985

UK CPV Survey code	Virulence characteristics	Octal designation
Rs-84-14	BRV-5	20
Rs-84-11	BRV-0	0
Rs-84-22	BRV-1,2,3,4,7	117

Results

The prolonged, rainy conditions during the spring and early summer of 1985 were conducive to the development of scald within the nurseries. Unfortunately, the ideal condition for the development of the disease resulted in the introduced isolates being swamped by naturally occurring infection. It is therefore difficult to make comparisons between cultivars with specific resistances. Quantitative differences were apparent between cultivars within individual nurseries, with each nursery showing a similar pattern of response. The results are summarised in Table 5a (winter cultivars) and Table 5b (spring cultivars). The spring barley cvs Osiris and MMG 7456/24/1 were resistant in all three nurseries. Cultivar Corgi which carries the Rh^4 resistant gene was resistant to octal race 117 but susceptible to octal race 20 which possesses virulence to this gene. It was also susceptible to octal race 0 which does not carry this virulence factor suggesting that the nursery inoculated with this isolate was contaminated with a BRV-5 isolate.

REFERENCES

JONES, E.R.L. & CLIFFORD, B.C. (1984). Rhynchosporium of barley. UK Cereal Pathogen Virulence Survey 1983 Annual Report. pp.60-63.

Table 5a. Percent infection in Rhynchosporium isolation nurseries - 1985

Winter cultivars	Isolate Rs-83-14 (BRV-5)	Isolate Rs-84-22 (BRV-1,2,3,4,7)	Isolate RS-84-11 (BRV-0)
	%	%	%
Maris Otter	18	38	27
Pipkin	27	30	22
Medallion	17	26	18
Vixen	17	20	27
Sonate	9	22	14
Halcyon	16	9	11
Nevada	14	9	14
Athene	12	18	11
Igri	15	13	9
Kaskade	12	10	15
Iceni	6	16	17
Libra	10	12	10
Impact	11	13	9
Tipper	11	11	10
Magie	8	11	8
Flamenco	11	6	7
Astrix	8	10	8
Sonja	3	11	10
Panda	5	10	6
Gerbel	8	5	8
Pirate	4	11	4
Monix	3	7	5
Hoppel	4	7	7
Opera	8	6	7
Marinka	3	6	4
Concert	2	4	3
Natalie	1	3	3
Metro	1	2	2
LSD	±7.51	±6.75	±3.50

% = $\bar{x}$ of 4 assessment dates and 4 replicates - isolates Rs-84-22 and Rs-84-11
% = $\bar{x}$ of 3 assessment dates and 4 replicates - isolate Rs-83-14

Table 5b. Percent infection in Rhynchosporium isolation nurseries - 1985

Spring cultivars	Isolate Rs-83-14 (BRV-5)	Isolate Rs-84-22 (BRV-1,2,3,4,7)	Isolate RS-84-11 (BRV-0)
	%	%	%
Natasha	27	29	39
Corniche	26	14	41
Patty	26	17	33
Doublet	24	20	45
Sherpa	23	24	27
Cameo	22	20	34
Acclaim	18	12	50
Flute	18	13	36
Kym	22	17	23
Klaxon	21	13	19
Golden Promise	17	17	20
Triumph	16	11	26
Delta	14	9	26
Midas	14	19	16
Apex	14	6	23
Golf	17	8	18
Atem	17	8	15
Regetta	14	10	18
Vista	11	7	15
Proctor	9	6	11
Armelle	6	3	0.1
La Mesita	30	14	13
Corgi	27	0.8	14
Digger	0.2	0.2	0.1
Osiris	0	0	0
LSD	±11.12	±8.99	±9.07

% = $\bar{x}$ of 3 assessment dates and 4 replicates - isolates Rs-83-14 and Rs-84-11
% = $\bar{x}$ of 2 assessment dates and 4 replicates - isolate Rs-84-22

NET BLOTCH OF BARLEY

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Eleven of the 15 isolates tested on seedlings in the glasshouse gave typical 'spotting' type lesions. Two of the differential cvs, CI 5401 and CI 9820, which are mostly resistant to the 'netting' isolates, were susceptible to all or some of the 'spotting' isolates. No isolate tested carried virulence compatible with the specific resistances of cvs C.I. 4795, C.I. 4502 and C.I. 9214. The winter barley cv. Marinka was resistant to all isolates. Two isolation nurseries were sown in the 1984-85 season. The cultivars showed a similar order of responses to the individual isolates although some evidence of specific host:isolate interactions was apparent. A wide range of susceptibility was observed within the winter cultivars.

GLASSHOUSE SEEDLING TESTS WITH 1985 ISOLATES

A total of 65 samples of net blotch was received in 1985. Fifty-seven were from winter cultivars and eight were from spring cultivars. The geographical origin of the samples is given in Table 1.

Location (ADAS Region)	No. of samples
East	44
West Central	11
North	8
South	1
Wales	1

The isolates of Pyrenophera teres Drechs. successfully cultured were inoculated onto seedlings of 13 differential cultivars plus 11 additional winter cultivars, using procedures described previously (Clifford & Jones, 1981).

Results

Viable cultures were made from only 15 of the samples. This was due to the presence of other fungi on the leaf samples of net blotch, which made the isolation of Pyrenophera teres difficult. The frequencies of virulence to each of the differential cultivars for the last four years are given in Table 2. Eleven of the samples tested, all from Morley, Norfolk, gave spotting type symptoms on the test cultivars. This symptom has been noted previously (Clifford, del Buono & Jones, 1984). The differential cv. C.I. 5401 and in particular cv. C.I. 9820 were very susceptible to isolates displaying these spotting symptoms, whilst these same isolates gave a more resistant reaction on the normally highly susceptible cv. Sonja. This confirms the pattern previously noted , whereby cultivars more susceptible to the spotting type tend to be more resistant to the typical 'netting' isolates (Clifford & Jones, 1985).

Table 1. Frequencies (%) of virulences corresponding to each differential cultivar (UK CPV Surveys 1982-1985)

Code number	Cultivar	1982	1983	1984	1985	Mean
1	C.I. 5401	8	0	0	14	6
2	C.I. 6311	20	0	22	21	16
3	C.I. 9820	6	0	0	56	16
4	C.I. 739	39	24	33	33	32
5	C.I. 1243	27	0	44	42	28
6	C.I. 4795	22	0	0	0	6
7	C.I. 4502	9	0	0	0	2
8	C.I. 4979	31	0	44	33	27
9	Proctor	-	52	55	90	49
10	Code 65 (W)	16	19	0	7	11
11	C.I. 9518 (W)	18	90	100	90	75
12	Tenn. 61-119 (W)	55	19	44	33	38
13	C.I. 9214	11	9	0	0	5
Number of isolates tested		83	21	9	15	32

(W) = Winter cv.

The spring cultivars C.I. 4795, C.I. 4502 and C.I. 9214 were resistant to all isolates. A low frequency of virulence was observed on the winter cv. Code 65 which corresponds with previous years' results. Cultivars Pirate and Gerbel appeared to be more resistant to the 'netting' type isolates but more susceptible to the 'spotting' type whereas cvs. Sonja and Pipkin showed a reverse trend. Cultivar Marinka was resistant to all isolates.

Virulences occurred in various combinations in the different isolates (Table 3).

Table 3. Virulence combinations and their frequencies (1985 isolates)

Virulence combination	Number of isolates	Type of symptom
11	1	S
3,10	1	S
3,11	1	S
9,11	1	S
9,11	1	N
3,9,11	2	S
3,9,11,12	1	S
3,4,9,11	1	S
1,3,5,8,9	1	S
1,3,5,9,11,12	1	S
2,4,5,8,9,11	1	N
4,5,8,9,11,12	1	N
2,4,5,8,9,11,12	1	N

S = 'Spotting' type
N = 'Netting' type

FIELD ISOLATION NURSERIES

Twenty-five winter and 20 spring barley cultivars were sown in each of two nurseries in 1984-1985, following standard procedures (Clifford, del Buono & Jones, 1984). The nurseries were inoculated with one or other of the following isolates:

Survey code	Virulence combination
BNS-84-4 (net)	2,4,5,8,9,11,12
BNS-80-12 (net)	7,8,9,10,11,12

Inoculation of the nurseries were carried out by spraying spore suspensions several times during the season, and also by introducing spores in the stems of the spreader cultivars by means of a hypodermic syringe.

Results

The cultivars were assessed throughout the season on the percentage leaf area infected. Results are given in Tables 4a and 4b.

Disease was slow to build up, but susceptible cultivars eventually developed high levels of infection. Infection amongst the winter cultivars was generally higher in the nursery inoculated with isolate BNS-80-12. The cultivars showed a similar order of responses to the individual isolates but there were exceptions to this, notably the spring barley cvs Golden Promise, Cameo and Midas which were more susceptible to isolate BNS-84-4. The winter barley cv. Concert was highly susceptible to both isolates which confirms observations at NIAB trial sites.

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Table 4a. Percent infection in net blotch isolation nurseries - 1985

Winter cultivars	BNS-80-12	BNS-84-4	Mean of 2 nurseries
Concert	23	13	18
Sonja	17	10	14
Flamenco	17	7	12
Tipper	11	7	9
Natalie	9	7	8
Pirate	9	7	8
Panda	8	4	6
Impact	7	5	6
Igri	7	4	6
Iceni	6	5	6
Halcyon	6	3	5
Nevada	6	3	5
Gerbel	6	4	5
Otter	6	3	5
Pipkin	5	1	5
Metro	4	2	3
Medallion	4	2	3
Monix	4	2	3
Vixen	4	1	3
Opera	3	3	3
Magie	3	1	3
Sonate	3	1	2
Libra	3	1	2
Kaskade	3	2	3
Marinka	2	2	2
LSD	3.9	3.0	

Winter cultivars = $\bar{x}$ of 3 scoring dates, 4 replicates
Spring cultivars = $\bar{x}$ of 2 scoring dates, 4 replicates

Table 4b. Percent infection in net blotch isolation nurseries - 1985

Spring cultivars	BNS-80-12	BNS-84-4	Mean of 2 nurseries
Golden Promise	5	14	10
MMG 7456/24/1	7	4	6
Doublet	5	5	5
Delta	4	5	5
Corniche	5	7	6
Acclaim	4	8	6
Flute	3	5	4
Sherpa	3	4	4
Klaxon	3	5	4
Vista	3	2	3
Cameo	3	9	6
Triumph	2	2	2
Regatta	2	2	2
Kym	1	3	2
Midas	2	7	5
Golf	1	1	1
Patty	1	2	2
Natasha	1	1	1
Apex	1	1	1
Atem	1	0	1
LSD	2.5	3.8	

Winter cultivars = $\bar{x}$ of 3 scoring dates, 4 replicates
Spring cultivars = $\bar{x}$ of 2 scoring dates, 4 replicates

MILDEW OF OATS

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A total of forty-five mildew samples were received from fairly well distributed localities and twenty four of the samples were successfully cultured. The trend observed in recent years continued in that the predominant virulence combination was the relatively complex OMV 1,2,3 (race 5) with 46% frequency, able to attack all commercial oat cultivars. The simpler race 3 (OMV 1,2), which race 5 has largely replaced, and which is unable to attack cultivars with OMR 3 resistance such as Avalanche, has nevertheless maintained its previous year's frequency level at 37%. There was an increase in virulence to Avena barbata (OMR 4) resistance, the virulence OMV 4 being combined with OMV 1,2 in one sample and with OMV 1,2,3 in three others.

Adaptation to adult plant resistance was investigated in seven cultivars using detached leaf segments and inoculum collected and subsequently 'trained' on each host. There was no conclusive evidence of adaptation in any of the mildew populations and, unlike the previous year, there was no suggestion of adaptation to the very high partial resistance of Rhiannon. This cultivar, together with OM 1387, showed high levels of resistance to all inoculum sources including 'own host' trained isolates suggesting the likelihood of durability of resistance.

SEEDLING TESTS WITH 1985 ISOLATES

A total of 45 samples of Erysiphe graminis avenae was received in 1985 of which six were from winter cultivars and the remainder from cultivars of spring oats. The 21 samples received from England were from the following ADAS regions: 6 from the North, 9 from East Central, 2 from the East, 3 from West Central and one from the South West. Twenty-one samples were also received from Wales and three from Eire. The 24 isolates which were successfully cultured were tested using methods described previously (Jones & 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 1985 compared with the previous three years is shown in Table 2. The predominant virulence combination in 1985, as 1984, was the relatively complex OMV 1,2,3 (race 5) with 46% frequency (Table 2). These virulence factors enable it to attack all cultivars on the 1985 and 1986 NIAB Recommended Lists of winter and spring oats. Its frequency, however, is not as high as in 1984 (64%) and has reverted to about its 1982 level. However, this virulence combination is also present in race 7 and the sum

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

Location	Cultivars	Virulences (OMV)
ENGLAND (East-central)		
Headley Hall, N. Yorkshire	Bulwark, Pennal	1,2
	Leanda, Trafalgar	1,2,3
ENGLAND (North)		
Cockle Park, Northumberland	Cabana, Leanda	1,2
	Avalanche, Rollo, Trafalgar	1,2,3
ENGLAND (South-west)		
Bicton College, Devon	Avalanche	1,2,3,4
WALES		
WPBS, Aberystwyth, Dyfed	Avalanche, Milo, Rollo	1,2,3
Morfa Mawr, Dyfed	Milo, Avalanche	1,2,3
	Dula	1,2,3,4
Trawscoed, Dyfed	Cabana, Trafalgar	1,2
	Rollo	1,2,3,
	Leanda	1,2,4
	Avalanche	1,2,3,4
Sarn, Powys	Trafalgar, Unknown variety	1,2
EIRE		
Leixlip, Co. Kildare	Cabana	1,2

Table 2. Virulence group frequencies identified from samples received in 1985 compared with previous three years

Virulence Group	Race	No. of isolates in 1985	Frequency (% total) 1982	1983	1984	1985
OMV 1	2	0	0	15	0	0
OMV 1,2	3	9	39	77	32	37
OMV 1,3	4	0	4	0	2	0
OMV 1,2,3	5	11	43	8	64	46
OMV 1,2,4	6	1	0	0	0	4
OMV 1,2,3,4	7	3	14	0	2	13
No. of isolates tested		24	28	13	41	24

of the frequencies of the two races (46% + 13%) is similar to the 1984 value of 66%. The frequency of OMV 1,2 (race 3) has maintained the same level as in 1984 having decreased from its 1983 peak. This simpler race, able to attack only cultivars with OMR 1 (Bulwark, Pennal) and OMR 2 (Cabana, Trafalgar) (Table 1) is selected against due to the increased hectarage in recent years of cultivars with OMR 3 resistance like Avalanche and Milo. However, there is probably as yet not enough area sown to such cultivars to effect a further decline in frequency and a corresponding increase in OMV 1,2,3 (race 5).

A feature of some concern in the 1985 survey is the considerable increase of virulence to Avena barbata (OMR 4) resistance (Table 2). The majority (13%) of this virulence has been found to be combined with OMV 1,2,3 making the isolates capable of attacking all available commercial cultivars. One sample (4%) lacked virulence to OMR 3 (Avalanche etc.) and was collected from the OMR 0 cultivar Leanda (Table 1). Also mildew from Dula, another OMR 0 cultivar, had OMV 4 combined with OMV 1,2,3, indicating that this virulence is not only combined with other long established virulences but that the new combinations are becoming well adapted in the field and able to compete satisfactorily with the simpler races. Nevertheless, there is no general failure of this resistance noted so far in the field; at WPBS advanced lines with A.barbata resistance in plots and material in the breeding nursery remained highly resistant during the 1985 season.

The simple races OMV 1 (race 2) and OMV 1, 3 (race 4) were not detected in the 1985 samples.

ADULT PLANT TESTS

Tests were carried out as in previous years to investigate whether adaptation to adult plant resistance was occurring in the mildew developed on various cultivars grown under field conditions.

Due to low levels of mildew the collection of spores directly on to leaf segments of the test cultivars, using the Schwarzbach spore-trap, proved unsatisfactory in this season. Consequently, leaf samples with mildew pustules were collected from plots at the end of July 1985 and multiplied on their respective host cultivars in separate spore-proof compartments and kept from July to January on seven successive lots of plants at 4-6 leaf stage before the testing procedure described below was carried out. The seven cultivars from which mildew was originally collected and also the seven test cultivars on which the isolates were subsequently tested were Selma, Milo, Rhiannon, Avalanche, Emrys and Rollo. Also included was the line OM 1387 with no known major genes for resistance, but with a high level of partial resistance. It was identified as a transgressive segregant with enhanced resistance from the cross of Selma x Maldwyn. The non-hypersensitive adult plant resistance of cv. Maldwyn was found to be complex histologically (Carver & Carr, 1978), genetically (Jones, 1986), and can be regarded as durable due to its effectiveness having lasted over 35 years (Jones, 1983).

The test cultivars were grown in a spore-free compartment and when ear emergence was just about to begin and flag leaves were fully emerged (G.S. 49-51) 2 cm segments from the flag leaves were cut and placed on benzimidazole agar in polystyrene boxes. Each box contained two blocks of the seven test cultivars randomised differently and two boxes (total of four blocks) were used for each of the seven inoculum sources.

A settling tower was used to deposit approximately 3000 spores per cm^2 on segments of each of the test cultivars. Segments inoculated with mildew from the OM 1387 isolate source received exactly half this number of spores due to shortage of inoculum. The leaf segments were inoculated on 31 January, placed in a controlled environment room at the beginning of a dark period, and incubated at 10 ± 2°C, 8 h light 16 h dark photoperiod under light intensity of 122 μ E m^{-2} s^{-1}. On 10 February 1986, after 10 days, the percentage leaf segment area showing mildew was recorded.

Results and Discussion

Mean values for percentage leaf segment area covered with mildew are presented in Table 3 and means after analysis of variance of the logit transformation of the original values are given in Table 4. All LSD values are given at P = 0.05 level of probability unless otherwise stated.

As in previous years Selma, a very susceptible cultivar with no known hypersensitive race-specific genes for resistance (OMR 0) was used as a control. However, in this experiment, and unlike the previous year's result, it was not the most susceptible, its overall mean value of 18.83% (Table 3) being exceeded, but not significantly (Table 4), by the means of Avalanche, Emrys and Rollo. A possible reason for this slightly more resistant response is that leaf 5 (leaf 1 = lowermost) was used in the 1984 test while the flag leaf was inoculated in the present experiment, and evidence is now available that an additive type genetic factor with small effect becomes effective in the upper leaves of Selma (Jones, 1986).

The overall means of Rhiannon (1.14%), a new naked oat, and OM 1387 (2.02%) are significantly lower (Table 4) than Selma or any of the other cultivars. These two cultivars show very low levels of infection to all the isolates (Table 3) including those multiplied on their own hosts. This suggests a horizontal type of resistance, and the lack of evidence of any adaptation means that these resistances could prove durable.

The overall inoculum source (isolate) means are similar apart from those of Milo and OM 1387. Both have slightly lower values of 11.03% and 10.08%, which may mean they are less aggressive, but as pointed out above less spores were produced and available for inoculation with OM 1387.

A comparison of a diagonal value (Table 3 and 4) with the values for that cultivar inoculated with the 'other host' isolates (i.e. values in the same row) gives an indication of any 'own host' adaptation. The diagonal values for Selma, Milo, Rhiannon, Emrys, Rollo and OM 1387 are not significanty higher than for the other values in their respective rows, thus no adaptive changes are evident in the mildew collected and 'trained' on these cultivars. With Avalanche, however, the value of

Table 3. Percentage leaf area infected with mildew on detached leaf segments of the flag leaves of seven test cultivars (means of four blocks)

Test cultivars		Inoculum source (isolates) Selma (OMR 0)	Milo (OMR 3)	Rhiannon (OMR 3)	Avalanche (OMR 3)	Emrys (OMR 3)	Rollo (OMR 2)	OM 1387 (OMR 0)	Mean
Selma	(OMR 0)	17.5	11.3	21.8	23.8	22.5	17.5	17.5	18.83
Milo	(OMR 3)	7.2	17.0	7.0	23.0	12.8	17.0	16.8	14.39
Rhiannon	(OMR 3)	0.2	0.8	0.4	1.2	0.8	3.2	1.4	1.14
Avalanche	(OMR 3)	22.5	9.3	45.0	38.8	36.2	26.8	11.0	27.08
Emrys	(OMR 3)	36.2	12.0	24.2	32.5	21.8	17.5	13.0	22.46
Rollo	(OMR 2)	35.0	22.2	31.2	17.5	18.0	18.8	10.8	21.93
OM 1387	(OMR 0)	0.9	4.6	6.0	0.02	0.2	2.2	0.2	2.02
Mean		17.09	11.03	19.38	19.52	16.04	14.71	10.08	15.41

Mean of 7 'own host' or homologous means = 16.36; Mean of 42 'other' or heterologous means = 15.25

Table 4. Percentage leaf area infected with mildew (x) on detached segments of the flag leaves of seven test cultivars (means of four blocks) (Logit transformation x + 0.1)

Test cultivars		Inoculum source (isolates) Selma (OMR 0)	Milo (OMR 3)	Rhiannon (OMR 3)	Avalanche (OMR 3)	Emrys (OMR 3)	Rollo (OMR 2)	OM 1387 (OMR 0)	Mean (LSD=±0.533)
Selma	(OMR 0)	-1.60	-2.80	-1.35	-1.19	-1.26	-1.62	-1.55	-1.625
Milo	(OMR 3)	-2.56	-2.04	-2.66	-1.50	-1.98	-2.12	-1.87	-2.104
Rhiannon	(OMR 3)	-5.94	-5.87	-5.51	-4.75	-5.36	-3.55	-5.29	-5.181
Avalanche	(OMR 3)	-1.24	-3.33	-0.22	-0.50	-0.64	-1.11	-2.38	-1.346
Emrys	(OMR 3)	-0.64	-2.28	-1.21	-0.73	-1.32	-1.72	-1.93	-1.404
Rollo	(OMR 2)	-0.62	-1.46	-0.82	-1.55	-1.59	-1.65	-2.23	-1.417
OM 1387	(OMR 0)	-5.42	-4.16	-2.98	-6.73	-5.84	-4.44	-6.11	-5.097
Mean (LSD=±0.533)		-2.574	-3.134	-2.106	-2.423	-2.569	-2.315	-3.053	-2.596

LSD to compare inoculum source/test cultivar means
= ±1.410 (P = 0.05), ±1.856 (P = 0.01), ±2.366 (P = 0.001)

Mean of 7 'own host' or homologous means = -2.67 ± 0.192 (n = 28);
Mean of 42 'other' or heterologous means = -2.58 ± 0.078 (n = 168); DF to test difference = 144

38.8%, although not significantly different from its values when inoculated with the isolates from Selma (22.5%), Rhiannon (45.0%), Emrys (36.2%) and Rollo (26.8%), nevertheless, is significantly higher than with the isolates from Milo (9.3%) and OM 1387 (11.0%) at P 0.001 and P 0.01 respectively (Table 4). A further test is to compare the value of 38.8% with the mean of the other values of that row. Using the logit values (Table 4) this difference becomes -0.50 - (-1.487) = +0.987, which was found to be non-significant, the calculated 't' value of 1.797 being less than 't' 144_{DF} of 1.96. The conclusion drawn from this is that although there is a tendency for 'own host' adaptation in Avalanche it is not significant.

Similar levels of infection would be expected on OMR 3 cultivars when inoculated by isolates from other OMR 3 cultivars, unless there were additional factors present in some such cultivars. With Milo and Rhiannon test cultivars, the isolates from the four OMR 3 cultivars produced statistically similar levels of mildew, although the levels varied considerably with Milo. With Avalanche, however, the isolate from Milo produced significantly less infection (9.3%, logit = -3.33) than the isolates from Rhiannon, Emrys and Avalanche itself. This suggests that Milo may lack a certain factor which is present in the other three in addition to the major OMR 3 resistance gene. Alternatively, this may simply result from the less aggressive nature of the Milo isolate, and as Milo, in general, shows higher levels of resistance than Avalanche in field plots further experimentation is necessary to clarify the reason for these differences. On the other hand it is quite evident that Rhiannon has a markedly higher level of partial resistance than the other OMR 3 cultivars, being considerably less infected in all tests and thus probably has additional factors for resistance expressed in the flag leaf.

In conclusion there is no clear evidence of adaptation in 1985 to the partial resistance of any of the seven cultivars tested. The overall mean of the 'own host' or homologous combinations (16.36%) was not significantly different from the heterologous combinations (15.25%) as tested in Table 4, which largely substantiates the above statements.

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CROWN RUST OF OATS

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Eight samples of oat crown rust were received in 1985. The geographical locations, host cultivars and races identified from the isolates of Puccinia coronata avenae cultured from these samples are given in Table 1.

Table 1. Location and cultivars from which oat crown rust samples were received in 1985

Sample code	Host cultivar	Location	Race
CRS-85-1	Peniarth	South-west	251
CRS-85-2	Peniarth	Wales	251
CRS-85-3	Breeding line	Wales	251
CRS-85-4	Rhiannon	Wales	251
CRS-85-5	Rhiannon	Wales	276
CRS-85-6	Rhiannon	Wales	251
CRS-85-7	Rhiannon	Wales	256
CRS-85-8	Rhiannon	Wales	251

Virulence patterns were determined on the International set of cultivars which are Anthony, Victoria, Appler, Bond, Landhafer, Santa Fé, Ukraine, Trispernia, Bondvic and Saia.

No new virulences were detected but two new virulence combinations were identified, one being race 276 which lacks virulence only to cvs Victoria and Saia. The other (race 256) lacks virulence to cvs Victoria, Santa Fé, Ukraine, Trispernia and Bondvic.

VARIETY DIVERSIFICATION SCHEMES FOR WINTER WHEAT AND WINTER AND SPRING BARLEY, 1986

Variety diversification schemes to reduce the spread of disease in winter wheat and spring barley have been produced by the UKCPVS Committee since 1975. This year, for the first time, the barley scheme has been expanded to include both winter and spring varieties. 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 principle and history of the UK diversification schemes has 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 and mildew of winter wheat and for mildew of winter and spring barley. 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 papers on 'Brown Rust of Wheat' in this and previous UKCPVS Annual Reports.

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VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST AND MILDEW IN WINTER WHEAT 1986

Severe infections may result if yellow rust or mildew spread between varieties which are susceptible to the same races of the pathogens. 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 or mildew. The Diversification Scheme should be used to choose winter wheat varieties to grow adjacent to each other.

Choosing varieties to grow together

1) Decide upon first-choice variety and locate its Diversification Group (DG).
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 or mildew
   y = risk of spread of yellow rust
   m = risk of spread of mildew

DG 1A
Brock
Mercia

DG 1B
Fenman

DG 1D
Ambassador
Corinthian

DG 1E
Aquila

DG 1G
Boxer
Mission

DG 2B
Virtue

DG 3B
Norman

DG 4C
Armada

DG 7A
Slejpner

DG 7D
Stetson

DG 8B
Galahad

DG 9B
Avalon
Brigand

DG 9F
Rapier

DG 11F
Moulin

DG 12B
Longbow

DG 13B
Brimstone

Chosen DG	Companion DGs: 1A	1B	1D	1E	1G	2B	3B	4C	7A	7D	8B	9B	9F	11F	12B	13B
1A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1B	+	m	+	+	+	m	m	+	+	+	m	m	m	m	m	m
1D	+	+	m	+	+	+	+	+	+	m	+	+	m	m	+	+
1E	+	+	+	m	m	+	+	+	+	+	+	+	m	m	+	+
1G	+	+	+	m	m	+	+	m	+	+	+	+	m	m	+	+
2B	+	m	+	+	+	ym	m	+	+	+	m	m	m	m	ym	m
3B	+	m	+	+	+	m	ym	+	+	+	m	m	m	ym	ym	m
4C	+	+	+	+	m	+	+	ym	+	+	+	+	m	m	+	+
7A	+	+	+	+	+	+	+	+	y	y	+	+	+	+	+	+
7D	+	+	m	+	+	+	+	+	y	ym	+	+	m	m	+	+
8B	+	m	+	+	+	m	m	+	+	+	ym	m	m	m	m	m
9B	+	m	+	+	+	m	m	+	+	+	m	ym	ym	ym	m	m
9F	+	m	m	m	m	m	m	m	+	m	m	ym	ym	ym	m	m
11F	+	m	m	m	m	m	ym	m	+	m	m	ym	ym	ym	m	m
12B	+	m	+	+	+	ym	ym	+	+	+	m	m	m	m	ym	m
13B	+	m	+	+	+	m	m	+	+	+	m	m	m	m	m	ym

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN BARLEY 1986

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
a) winter barley or spring barley varieties to grow adjacent to each other and
b) spring barley varieties to grow adjacent to winter barley.

Choosing varieties to grow together

1) Decide upon 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
Concert (W)
Gerbel (W)
Halcyon (W)
Igri (W)
Panda (W)
Pirate (W)
Magie (W)
Maris Otter (W)
Corgi (S)
Golden Promise (S)

DG 1
Nevada (W)
Opera (W)
Sonate (W)
Tipper (W)
Apex (S)
Atem (S)
Camargue (S)
Regatta (S)

DG 2
Midas (S)

DG 3
Golf (S)
Koru (S)

DG 4
Goldmarker (S)

DG 5
Kaskade (W)
Patty (S)
Piccolo (S)

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

DG 7
Celt (S)
Delta (S)
Flute (S)
Vista (S)

DG 8
Tweed (S)

DG 9
Doublet (S)
Klaxon (S)

DG 10
Egmont (S)
Regent (S)

DG 11
Cameo (S)
Kym (S)

DG 12
Acclaim (S)
Corniche (S)
Heriot (S)
Natasha (S)

DG 13
Pipkin (W)
Digger (S)
Sherpa (S)

Chosen DG	Companion DGs													
	DG0	DG1	DG2	DG3	DG4	DG5	DG6	DG7	DG8	DG9	DG10	DG11	DG12	DG13
DG0	m	m	m	m	m	m	m	m	m	m	m	m	m	m
DG1	m	+	+	+	+	+	+	+	+	+	+	+	+	+
DG2	m	+	m	+	m	+	+	+	+	+	+	+	+	+
DG3	m	+	+	m	m	+	+	+	+	m	m	m	+	+
DG4	m	+	m	m	m	+	+	+	+	m	+	+	+	+
DG5	m	+	+	+	+	m	+	+	+	+	m	+	m	+
DG6	m	+	+	+	+	+	m	+	+	m	+	+	m	+
DG7	m	+	+	+	+	+	+	m	+	+	+	+	+	+
DG8	m	+	+	+	+	+	+	+	m	+	+	m	+	+
DG9	m	+	+	m	m	+	m	+	+	m	+	+	+	+
DG10	m	+	+	m	+	m	+	+	+	+	m	+	+	+
DG11	m	+	+	m	+	+	+	+	m	+	+	m	+	+
DG12	m	+	+	+	+	m	m	+	+	+	+	+	m	+
DG13	m	+	+	+	+	+	+	+	+	+	+	+	+	m