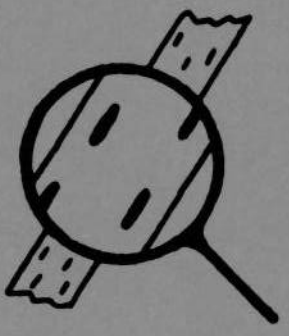
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1984 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

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 1984

Mildew of Wheat

Mean pathogenicity values were similar to last year, WMV 2 and WMV 2+6 being the most common pathogenicities. WMV 7 became more common, reflecting an increase in the acreage of the cultivar Stetson (WMR 7+?). There are no obvious interactions between different pathogenicity characters, complex pathogenicity combinations being found in samples from cultivars containing only one recognised resistance component. Insensitivity to the triazole fungicides increased overall in 1984 compared with 1983. However, fluctuations in levels of insensitivity occurred throughout the year, depending on selection for insensitivity due to fungicide application and competition from sensitive isolates.

Yellow Rust of Wheat

A large proportion of 1984 isolates were from crops of the cultivar Longbow and possessed the virulence combination WYV 1,2,6. The unusual virulence combination WYV 1,2,4 was identified in several isolates taken from inoculated adult plants. These were virulent on the previously resistant cultivars Brimstone and Fenman (at the seedling stage). One 1983 isolate possessed the virulence combination WYV 13,14, the first time that combined adult plant virulence has been detected by the Survey.

Brown Rust of Wheat

In field isolation nurseries, one isolate (WBRS-83-11H) gave higher levels of infection on Maris Ranger than had previously been observed. The adult plant, temperature-sensitive resistances of cvs Virtue, Hustler and Rapier remained effective against all four isolates tested in the field. Cvs Gawain, Moulin, Brimstone and Axona also expressed adult plant resistance to these four isolates.

Mildew of Barley

Pathogenicity for cv. Triumph predominated in England and increased in Scotland. Low levels of insensitivity to triazole fungicides were common throughout England and Scotland, and higher levels increased in frequency in eastern England. N. Irish figures for barley mildew virulence frequency were in broad agreement with those from England, with the exception of the combined virulences BMV 4+5 and BMV 3+4, which, as in 1983, were at a considerably higher frequency in N. Ireland.

Yellow Rust of Barley

Six of the seven isolates received in 1984 possessed BYV 3, the virulence for seedlings of Triumph and related cultivars which was first detected in 1983. However, there was no firm evidence that isolates possessing BYV 3 produced higher levels of infection on adult plants of BYR 3 cultivars than did those lacking BYV 3.

For the second year, a 1982 isolate from winter barley produced high levels of infection on adult plants of a wide range of winter barley cultivars.

Brown Rust of Barley

The number of isolates carrying virulence to cv. Triumph continues to increase and comprised 88% of the 1984 isolates. Winter cultivars were all susceptible to a Triumph-virulent isolate when tested in a field nursery but showed quantitative differences in infection.

Rhynchosporium of Barley

In seedling tests of winter cultivars, cv. Gerbel was resistant to all isolates and cv. Tipper was resistant to all but three. Cv. Pirate was resistant to all isolates carrying BRV 1, but this may be a spurious correlation. The exceptionally dry season made field data difficult to interpret.

Net Blotch of Barley

Isolates carrying between 1 and 7 specific virulences in various combinations were identified from isolates of Pyrenophora teres Drechs. tested on seedlings. In field tests of P. teres F. maculata, which causes spotting-type lesions, winter cultivars showed a reverse order of resistance compared with 'netting' isolates. Cultivars carrying the Rhynchosporium resistance gene Rh^4 were susceptible to the 'spotting' isolate.

Mildew of Oats

In a year of generally high levels of oat mildew the most prevalent virulence combination was OMV 1,2,3 (race 5) which attacks all hypersensitive type resistances in present day commercial oats. One sample possessed virulence to the Avena barbata resistance factor OMR 4, which has not yet been released in commerce. There was some indication that adaptation may be occurring to the high level of adult plant resistance of the cv. Rhiannon, but the resistance level of Orlando and Milo has been maintained.

Crown Rust of Oats

One new virulence combination, namely race 417, virulent on Appler, Bond and Landhafer was identiffied from cv. Rhiannon grown in Dyfed, Wales. The individual virulences have been previously identified.

MILDEW OF WHEAT

R.W. Summers and Thea M.C. van Kints

Plant Breeding Institute, Cambridge

Mean pathogenicity values have changed little since 1983. WMV 2 and WMV 2+6 were the most common pathogenicities in 1984. This reflects the large acreage of cultivars with WMR 2 and WMR 2+6. WMV 7 has become more common, probably due to an increase in the acreage of the cultivar Stetson (WMR 7+?). In addition to WMR 7, there is some evidence that Stetson contains WMR 5+8. The cultivar Hammer (WMR 7+?) does not contain WMR 5+8 but other additional, unknown, resistant components.

Comparisons between direct and indirect scores indicated that the scoring methods give different results. Direct methods give results which most accurately reflect the mildew population structure and will be used in preference to indirect methods for the 1985 survey.

Insensitivity to the triazole fungicides increased in 1984. Insensitivity is a dynamic character and levels fluctuated throughout the year due to selection pressure from fungicide application. Levels increased to a peak in late June and then declined in early August. The negative association between insensitivity and WMV 4 was observed again in 1984. However, this negative association may be a reflection of a lack of selection for a positive association between WMV 4 and insensitivity.

INTRODUCTION

The relative frequencies of specific pathogenicity characters and the levels of insensitivity to the triazole fungicides were determined using the indirect and direct scoring methods described in the 1983 virulence survey report (Bennett and van Kints, 1984). Five new cultivars, belonging to three different WMR groups, have been added to the differential set (Table 1); Boxer, (WMR 4+8), Brock and Renard (WMR 2 + Talent) and Solitaire and Wembley (WMR Sona). However, the differential set of seedlings and the fungicide set of seedlings used for survey work remained the same as the sets used in 1983 (Bennett and van Kints, 1984).

There was a severe epidemic of wheat powdery mildew in 1984. The disease built up to high levels in the previous autumn but development was retarded in February and March due to heavy frosts. Mildew became active again in mid-April and by late June flag leaves and ears were heavily infected, mildew being recognised as the most prominent disease (ADAS Disease Intelligence Reports, October 1983 to July 1984).

METHODS

Mildew isolates obtained from leaf samples received in 1984 were maintained in cooled incubators on seedling leaf segments of the susceptible cultivar Cerco. Successive generations of mildew were transferred aseptically to clean, fresh, leaf segments. The isolates were tested to the differential set to obtain indirect scores for mean pathogenicity values, as described previously (Bennett and van Kints, 1982).

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

WMR group	Gene	Differential cultivar
0	-	Hobbit
1	Pm1	Anfield
2	Pm2	Bounty
3	Pm3a, 3b, 3c	Asosan, Chul, Sonora
4	Pm4a, 4b	Khapli, Armada
5	Pm5	Hope
6	Pm6	Timgalen
-	Pm7	Transec
7	Pm8	Stuart
8	'M1i'*	Flanders
9	Pm2+'M1d'*	Maris Dove
2+4		Sappo
2+6		Brigand
4+8		Mission, Boxer
7+?		Stetson
7+?		Hammer
5+8+?		Sicco
2+4+6		Timmo
2+6+7		CWW1645/5
2+6+8		Crossbow
2+Talent		Brock, Renard
Sona		Solitaire, Wembley

* Temporary symbols
Cultivars used in the differential set are underlined

A succession of Cerco seedlings were exposed at intervals, on a garage roof in the Cambridgeshire village of Over, from November 1983 to November 1984. The bulked mildew isolates obtained from the static seedling nurseries were maintained on Cerco seedling leaf segments and tested to the differential set to obtain indirect scores for mean pathogenicity values.

The wind impaction spore trap (WIST, Bennett and van Kints, 1981) was used to obtain direct and indirect scores for mean pathogenicity and fungicide insensitivity values. Seedlings of cultivars with unknown resistance components were also exposed in the WIST in an attempt to find matching pathogenicity in the mildew population.

Direct tests were carried out by exposing the differential and fungicide sets (see Table 1 and 3) in the WIST. The number of mildew colonies which developed on differential seedlings and on seedlings grown from seed treated with known concentrations of triadimenol were compared to the number of colonies which developed on untreated seedlings of Hobbit and Cerco (both WMR 0). These comparisons gave direct scores for mean pathogenicity and fungicide insensitivity values.

To obtain indirect scores for mean pathogenicity values, mildew colonies which developed on Hobbit or Cerco seedlings after exposure in the WIST were bulked and maintained on Cerco seedling leaf segments. The bulk isolates were tested to the differential set before maintenance, after one generation of maintenance and after >5 generations of maintenance.

Table 2. Details of leaf samples received in 1984

WMR group	Source cultivar	Number received	Fungicide treated	Number tested
0	Cerco	1		0
	Jerico	4		2
	Minaret	6		5
	Moulin	1		0
	Rapier	3	1	2
2	Avalon	4		3
	Fenman	2		1
	Galahad	2		1
	Longbow	2		1
	Norman	2		0
3	Chul	1		
4	Armada	5	2	3
8	Aquila	2		2
	Flanders	2	1	2
2+6	Brigand	2		0
	Brimstone	2		0
	Gawain	2		2
	Virtue	2		0
4+8	Boxer	7		4
	Mission	6		3
7+?	Hammer	6		4
	Stetson	9	3	7
2+4+6	Timmo	4		1
5+8+?	Broom	5		4
	Sicco	4		3
2+Talent	Brock	3		2
	Renard	4		3
Sona	Solitaire	3		3
	Wembley	4		2
?	Axona	1		0
	Musket	4		1
	Tonic	5		3
(triticale)	Lasko	2		2
	Rht	1		1
	Twyfords 3+4	1		0

To obtain indirect scores for fungicide insensitivity values, bulk mildew isolates were also obtained from Hobbit or Cerco seedlings. If a bulk isolate was obtained from untreated seedlings it was maintained on untreated Cerco seedling leaf segments. Bulk isolates obtained from treated seedlings were maintained on untreated Cerco seedling leaf segments and on Cerco leaf segments from seedlings grown from triadimenol treated seed (0.04 g a.i. triadimenol kg^{-1} seed). The bulk isolates were tested to the fungicide set.

RESULTS AND DISCUSSION

Details of leaf samples received and samples caught in the WIST in 1984 are given in Tables 2 and 3.

Table 3. Details of WIST samples collected in 1984

WMR Group	Trap cultivar	Seed treatment (g triadimenol kg^{-1})	Number collected
0	Cerco	Untreated	75
		0.04	72
		0.125	57
0	Hobbit	Untreated	35
		0.04	13
		0.08	11
		0.125	12
		0.25	8
		0.375	6
		0.625	3
7+?	Hammer	Untreated	1
?	MD2	Untreated	3
?	MD37	Untreated	1
?	Tonic	Untreated	3
?	Musket	Untreated	1
?	Lasko (triticale)	Untreated	6

Mildew colonies were occasionally found on seedlings of the cultivars MD 2 and MD 37, after exposure in the WIST (Table 3). These cultivars are sister lines originally recognised as being completely resistant (PBI, AR 1982). The cultivars were exposed each week during May and one mildew colony was found on MD 2 on three occasions and on MD 37 once. Conidia from the colonies on MD 2 and MD 37 seedlings were unable to re-infect MD 2 and MD 37 seedling leaf segments. Conidia from mildew colonies found on Lasko seedlings exposed in the WIST re-infected Lasko seedling leaf segments poorly. After three generations no re-infection occurred and the mildew had to be maintained on Cerco seedling leaf segments.

Differential tests

Table 4 gives the mean pathogenicity values for the bulk isolates from leaf samples tested to the differential set. There were no obvious interactions between pathogenicity characters; complex pathogenicity combinations being found in samples from cultivars containing only one resistance component. One isolate from Hammer was not pathogenic on Stetson, confirming that these two cultivars contain different resistance components. The Hammer isolate was also not pathogenic on the differential cultivars containing WMR 5 or WMR 8, whereas all the Stetson isolates were. This confirms last year's observation (Bennett and van Kints, 1983) that Stetson might contain WMR 5+8 as well as WMR 7.

Table 4. Mean pathogenicity of 67 bulk isolates from leaf samples received in 1984

WMR Group	Source cultivar	Wheat mildew virulence (WMV) group as represented by differential cultivars*												No. of Isolates
		2	4	5	6	7	8	2+6	4+8	2+4+6	2+6+7	5+8+?	Stetson	Hammer	
0	Jerico	65	40	56	46	0	54	68	18	36	0	45	0	0	2
	Minaret	89	39	98	82	17	91	128	31	15	13	42	19	2	5
	Rapier	50	33	64	77	0	60	69	14	0	1	0	1	0	2
2	Avalon	76	65	75	49	33	100	77	47	19	3	19	37	4	3
	Fenman	74	70	89	74	0	85	93	81	0	0	0	0	0	1
	Galahad	65	63	82	41	84	68	48	82	34	50	52	117	58	1
	Longbow	63	79	92	60	0	47	89	72	57	0	54	0	0	1
4	Armada	74	85	62	38	1	63	58	83	34	1	27	21	3	3
8	Aquila	85	54	77	81	5	81	110	39	0	5	0	4	5	2
	Flanders	55	36	103	82	0	107	102	45	34	1	31	1	0	2
2+6	Gawain	86	3	73	82	1	72	103	1	0	1	24	2	1	2
7+?	Hammer	71	0	72	81	83	61	94	0	0	84	4	82	85	4
	Stetson	61	16	73	35	91	70	30	23	6	45	12	96	36	7
2+4+6	Timmo	95	87	104	80	25	74	98	67	99	0	99	0	0	1
2+4+8	Boxer	75	92	65	60	0	73	105	90	60	0	52	7	0	4
	Mission	76	83	90	51	19	93	70	69	27	4	20	42	0	3
5+8+?	Broom	109	54	91	79	18	105	59	65	36	30	56	27	20	4
	Sicco	56	35	82	67	0	65	76	28	35	0	65	0	7	3
2+Talent	Brock	90	46	92	88	0	77	106	42	0	3	4	0	0	2
	Renard	87	7	57	100	0	44	107	8	1	0	15	0	0	3
Sona	Solitaire	97	80	84	100	0	126	126	95	71	1	95	0	0	3
	Wembley	61	41	72	58	0	60	98	55	35	0	32	0	0	2
?	Musket	78	53	98	1	0	74	1	92	1	0	93	0	0	1
	Tonic	50	97	32	39	0	32	82	49	67	0	17	0	0	3
Triticale	Lasko	72	1	41	84	0	35	81	1	0	0	0	0	0	2
	Rht3	69	69	89	64	7	72	0	79	1	0	94	2	1	1

* Differential cultivars given in Table 1.

Table 5. Comparison of mean pathogenicity of leaf sample isolates (excluding values for samples from cultivars with matching resistance) with WIST sample isolates from untreated cv. Cerco seedlings (1983-84) and roof trap sample isolates from untreated cv. Cerco seedlings (1984)

Type of isolate	Year	WMV group as represented by differential cultivars* 2	4	5	6	7	8	2+6	4+8	2+4+6	2+6+7	5+8+?	Stetson	Hammer	No. of Isolates
CPVS leaf isolates	1982	86	15	63	59	0	64	71	-	2	1	13	0	-	18
	1983	85	37	73	64	1	80	75	26	20	6	30	1	1	35
	1984	72	39	74	64	8	69	82	41	24	10	28	17	7	67
mean	82-84	81	30	70	62	3	71	76	34	15	6	24	6	4	(120)
WIST isolates	1982	96	35	68	73	2	80	96	-	17	1	16	2	-	17
	1983	89	42	69	72	1	67	75	33	14	0	20	0	1	36
	1984	82	49	66	64	7	57	90	40	30	6	31	5	5	29
mean	82-84	89	42	68	70	3	68	87	37	20	2	22	2	3	(82)
Roof trap isolates	1984	82	49	60	52	0	59	81	44	26	1	17	0	0	26

* Differential cultivars given in Table 1

Table 6. Mean pathogenicity of mildew populations, tested directly by counting the colonies which developed on a differential set of cultivars exposed in the WIST, compared with bulked isolates from the same populations, taken from cv. Hobbit. The bulked isolates were tested indirectly to a differentential set, a) before maintenance, b after maintenance for one generation, c) after maintenance for more than five generations. Isolates were maintained on untreated cv. Cerco leaf segments

Testing method	WMV group as represented by differential cultivars*													No. of samples
	2	4	5	6	7	8	2+6	4+8	2+4+6	2+6+7	5+8+?	Stetson (i)	Hammer (ii)	
Direct	198	47	205	36	10	171	186	40	31	23	32	8	38	14
Indirect: Before maintenance	89	45	64	65	5	61	82	40	35	8	26	4	5	14
1 generation	95	35	57	53	4	65	91	27	18	6	14	1	4	14
>5 generations	87	55	67	65	1	73	109	47	29	4	35	0	2	14
Decline in pathogenicity after maintenance	-	-	-	-	yes	-	-	-	-	yes	-	yes	yes	

* Differential cultivars given in Table 1.

The relative frequencies of mean pathogenicity values of mildew isolates obtained from leaf samples, the WIST and roof seedling nurseries gave similar distributions (Table 5). The frequencies of WMV groups have changed little from previous years, WMV 2 and WMV 2+6 being the most common pathogenicities. The frequency of WMV 7 does appear to have increased in isolates from leaf samples and WIST catches. Presumably this reflects an increase in the acreage of Stetson (WMR 7+?) in 1984, as a consequence of the inclusion of this cultivar on the NIAB Recommended List. Isolates from the roof trap nurseries did not contain WMV 7. The roof trap was located near commercial wheat crops and the absence of WMV 7 from the isolates caught might be because cultivars containing WMR 7 were not grown in the area.

Table 6 gives the results of the comparison between direct and indirect scoring methods to obtain mean pathogenicity values. The largest difference occurs between the direct scores and indirect scores made before maintenance. This demonstrates that even though the cultivar Hobbit, the source of isolates for the indirect tests, contains no recognised resistance components (WMR 0), it does have a selective effect on the mildew population. Changes in mean pathogenicity values during maintenance do occur and WMV groups containing WMV 7 appear to decline steadily (see Bennett and van Kints, 1983, for confirmation). However, these changes are small compared to those between direct and indirect scores.

These results demonstrate that direct scores give more reliable information on the structure of wheat mildew populations. Hence, to increase our understanding of the population dynamics, direct scoring methods will be used in 1985.

Fungicide insensitivity tests

A comparison of the mean pathogenicity values of WIST samples collected on seedlings grown from untreated or triadimenol treated seed suggested that a negative association exists between WMV 4 and fungicide insensitivity (Table 7).

Table 7. Mean pathogenicity matching selected host resistances in samples collected in the WIST on untreated (-) and treated (+) seedlings of different cultivars

Trap cultivar	Conditions of sample collection	WMV group as represented by different cultivars*										Number of Samples	
		4		4+8		2+4+6		5+8+?		Mean others[1]			
		-	+	-	+	-	+	-	+	-	+	-	+
Hobbit	All	41	18	38	15	31	5	27	11	42	44	28	8
Cerco	All	49	19	40	7	30	6	27	6	40	39	29	34
Cerco	Cambs	51	6	51	6	37	2	26	4	43	40	12	14
Cerco	Essex	50	36	28	12	17	14	14	10	37	38	9	13
Cerco	Pre 1 June	62	20	52	9	38	8	30	18	43	36	22	26
Cerco	Post 1 June	10	16	2	1	4	1	15	1	38	41	7	8

* Differential cultivars given in Table 1
[1] Includes WMV 2, 5, 6, 7, 8, 2+6, 2+6+7, Stetson, Hammer

In an attempt to confirm the existence of a negative association, a bulk isolate from a triadimefon treated Armada (WMR 4) crop, was tested to the fungicide set. No colonies developed on leaf segments from seedlings grown from

triadimenol treated seed. These observations, indicate that the negative association is a true phenomenum, and verify the findings of previous surveys (Bennett and van Kints, 1982, 1983). It would be unwise to conclude that a positive association between fungicide insensitivity and WMV 4 could not occur. At present, however, the survey results indicate that cultivars containing WMR 4 would benefit more than other cultivars from a triazole spray. Careful monitoring of the pathogen population to determine the permanency of the negative association will be necessary.

Direct tests for fungicide insensitivity were carried out by exposing the fungicide set of seedlings in the WIST each week from May to August. Levels of insensitivity again increased in 1984, compared with 1982 and 1983 levels (Table 8).

Table 8. Colony number on cv. Cerco seedlings grown from seed treated with triadimenol at the stated dose, relative to the number on untreated cv. Cerco seedlings. Seedlings were exposed in the WIST at intervals between May and August, 1982 - 1984, in Cambridgeshire

Year	Dose rate (g a.i. kg^{-})*	
	0.04	0.125
1982	25	6
1983	51	18
1984	69	33

* Normal field rate 0.375 g a.i. kg^{-1}

There is considerable variation in the mildew population for fungicide insensitivity, as shown by indirect tests of WIST isolates collected on untreated and treated seedlings (Table 9 and 10).

Table 9. Colony number on cv. Hobbit leaf segments grown from triadimenol treated seed, relative to the number on untreated segments, for bulk isolates collected from seedlings, grown from treated seed, exposed in the WIST during 1983 and 1984. Bulk isolates were maintained on cv. Cerco leaf segments grown from untreated and treated seed

Year of WIST collection	Seed treatment concentration (maintenance) leaf segments) (g a.i. $kg^{-}1$)	Seed treatment concentration (test leaf segments) (g a.i., kg^{-1})						No. of isolates
		0.04	0.08	0.125	0.25	0.375	0.625	
1983	tested before maintenance	41	24	16	7	6	2	26
	untreated	40	21	5	0	0	0	25
	0.04	51	26	8	4	1	0	14
1984	untreated	59	33	20	4	2	0	61
	0.04	75	59	30	11	4	1	61

Because such variation exists, it is likely that if the trend for increased triazole usage continues, levels of insensitivity in the mildew population will correspondingly increase. The dynamic nature of fungicide insensitivity is demonstrated by the changes in the insensitivity levels expressed by isolates after maintenance on untreated or treated seedling leaf segments (Table 9). The changes in levels of insensitivity which occur during maintenance indicate that direct tests give the best estimates of levels of insensitivity in mildew populations.

Table 10. Colony number on cv. Hobbit leaf segments grown from triadimenol treated seed, relative to the number on untreated segments, for bulk isolates collected from cv. Hobbit seedlings, grown from untreated and treated seed, exposed in the WIST. Bulk isolates were maintained on cv. Cerco leaf segments grown from untreated seed

Seed treatment concentration (trap seedlings) (g a.i. kg^{-1})	Seed treatment concentration (test leaf segments) (g a.i. kg^{-1})						No. of isolates
	0.04	0.08	0.125	0.25	0.375	0.625	
Untreated	1	2	0	0	0	0	3
0.04	47	21	9	1	0	0	4
0.08	44	24	12	4	3	2	8
0.125	58	39	22	9	2	0	9
0.25	53	40	16	5	1	0	6
0.375	52	46	25	1	0	0	4
0.625	65	50	16	6	0	0	2

ADAS advice to farmers (ADAS Disease Intelligence Reports, October 1983 to July 1984) suggested to us that the major application of triazole fungicides would occur at the end of May. To assess changes in sensitivity due to triazole application, levels of fungicide insensitivity of WIST isolates collected before and after 1st June 1984 were compared (Table 11).

Table 11. Colony number on cv. Hobbit leaf segments grown from triadimenol treated seed, relative to the number of untreated segments, for bulk isolates collected from cv. Cerco seedlings, grown from untreated or treated seed, expkosed in the WIST before and after 1 June 1984. Bulk isolates were maintained on cv. Cerco leaf segments grown from untreated seed

Seed treatment concentration (trap seedlings) (g a.i. kg^{-1})	Period of sampling relative to 1 June	Seed treatment concentration (test leaf segments) (g a.i. kg^{-1})						No. of isolates
		0.04	0.08	0.125	0.25	0.375	0.625	
Untreated	before	14	5	1	0	0	0	12
	after	16	11	4	0	0	0	9
0.04	before	55	30	24	5	0	0	6
	after	50	25	13	1	0	0	18
0.125	before	63	48	18	8	1	0	8
	after	59	23	17	3	1	0	18

Contrary to the results of last year's survey (Bennett and van Kints, 1983) levels of insensitivity, before and after the predicted major application of triazole fungicides, did not appear to change significantly. This may reflect increased usage of triazole fungicides throughout the year, leading to more constant selection pressure for insensitivity than occurred in 1983.

Although insensitivity to the triazole fungicides has increased there were no reports of inadequate control of wheat powdery mildew during 1984. To gain a better understanding of the situation, changes in the proportion of the population insensitive to the triazoles must be monitored frequently throughout the year. In 1984 the proportion of the population insensitive to the 0.04 g a.i. triademenol kg^{-1} seed treatment was 23% in April, 100% at the peak of the epidemic in July, and 44% in late August, when the population had declined following the wheat harvest (Summers and van Kints, unpublished). Knowledge of the survival of insensitive individuals and their contribution to any following mildew epidemics would be most relevant to any predictive studies of the speed of selection for insensitivity.

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YELLOW RUST OF WHEAT

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Forty-one samples were received during 1984, from which 36 isolates were made and tested. The virulence combination WYV 1,2,6 was identified in 39% of isolates, reflecting the relatively large number received from crops of Longbow (WYR 1,2,6). The unusual virulence combination WYV 1,4 was detected in several isolates taken from inoculated adult plant tests. All of these were virulent on Brimstone and most were also virulent on Fenman (at the seedling stage). Eight isolates from the 1983 Survey were tested in adult plant tests. One isolate possessed combined virulence for the adult plant resistances WYR 13 and WYR 14.

INTRODUCTION

The principal aims and methods involved in the wheat yellow rust survey have been described by Priestley (1978). Specific resistances (WYR Factors) identified in wheat cultivars to date, the resistance genes where known, a test cultivar possessing each resistance and the year of first detection of virulence (WYV) in the UK population of Puccinia striiformis are given in Table 1.

Table 1 Resistance factors to Puccinia striiformis

WYR Factor	Gene	Type*	Test Cultivar	WYV detected
WYR 1	Yr1	Overall	Chinese 166	1957
WYR 2	Yr2	Overall	Heine VII	1955
WYR 3	Yr3a+4a	Overall	Vilmorin 23	1932
WYR 4	Yr3b+4b	Overall	Hybrid 46	1965
WYR 5	Yr5	Overall	T. spelta album	.
WYR 6	Yr6	Overall	Heines Kolben	1958
WYR 7	Yr7	Overall	Lee	1971
WYR 8	Yr8	Overall	Compair	1976
WYR 9	Yr9	Overall	Riebesel 47/51	1974
WYR 10	Yr10	Overall	Moro	.
WYR 11	-	Adult plant	Joss Cambier	1971
WYR 12	-	Adult plant	Mega	1969
WYR 13	-	Adult plant	Maris Huntsman	1974
WYR 14	-	Adult plant	Hobbit	1972

* = sensu Zadoks. Overall resistances are effective at all growth stages, adult plant resistances are ineffective at seedling growth stages.

. = virulence not yet detected.

METHODS

Seedling tests with 1984 isolates

Forty one samples were received during 1984, of which 22 were from commercial crops, mostly in coastal areas of Lincolnshire. The remainder of the isolates were from variety trial plots at NIAB headquarters in Cambridge. The total number of samples was about half that received in 1983, reflecting the generally poor conditions for development of yellow rust in 1984, when a hot, dry period in late April was followed by a warm and dry summer, with few periods suitable for infection. The samples were collected in a non-random way from Longbow (15), Norman (4), and 22 samples from 17 other cultivars.

Isolates were made successfully from 36 samples, and seedling tests carried out to determine the presence of virulence factors compatible with the overall specific resistances WYR 1-10 (Table 1). Fenman, Brimstone and Boxer were included as additional test cultivars as they had been resistant to all isolates in previous years.

Three isolates of yellow rust were made from samples collected from Triticale cultivars grown on NIAB trial ground, Cambridge. In seedling tests these were all shown to possess WYV 1,2,3.

Adult plant tests with 1983 and control isolates

Nineteen isolates were tested for virulence compatible with adult plant resistances, using the Polythene tunnel technique described by Priestley, Bayles and Thomas (1984). Seedling tests were carried out with the same isolates in controlled environment chambers (16 hour day at 18°C, 8 hour night at 11°C). The isolates (Table 2) comprised nine controls of known virulence, seven collected from the 1983 Survey, and three re-isolated from inoculated plots in 1983.

In Polythene tunnel tests, two replicate tussocks of 36 cultivars were sown on 24th-25th November, inoculated on 23rd March and 7th April, and assessed for percentage leaf area infected on 1st May (GS 32), 10th May (GS 38), 21st May (GS 45) and 1st June (GS 52).

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

Code	Cultivar	Region*	Site	WYV Factors**
Control isolates				
76/71	Grenade	S	Mains of Ravensby	1,2,3,13
82/29	Stetson	SE	Wye	1,2,3,9
81/34	Vuka	SE	Sparsholt	2,3,4,9
71/493	Capta	S	Duns	1,2,3,7
P81/20	Moulin	E	PBI Trial Ground	3,4,6,14
P81/12	CWW1684/15	E	PBI Trial Ground	2,3,4,6,12,13,14
P79/4	TL363/30/2	E	PBI Trial Ground	1,2,3,14
P631	Maris Templar (inoculated plot, PBI)			1,(2),3,4,(6),7
P75/27	Hobbit (inoculated plot, PBI)			2,3,4,14
1983 Survey isolates				
83/96	Moulin	E	Holbeach	2,3,4,6
83/10	Hammer	SE	Oxford	1,2,3,9
83/44	Hammer	SE	Oxfordshire	1,2,3,9
83/39	Stetson	E	Harpenden	1,2,3,9
83/28	CF698615/3	WM	Harper Adams	1,2,3,(4)
83/62	Longbow	E	Norfolk	1,2,3,6
83/53	MMG9874/4	E	Lincs	1,2,3
Other Isolates				
76/71R	Maris Huntsman inoculated with 76/71			1,2,3,13
P75/27R	Hobbit inoculated with P75/27			2,3,4,14
83/A3	Longbow inoculated with 82/A1			1,2,3,6

( ) = partially virulent on corresponding resistance.

* S = Scotland, SE = South East, E = East, WM = West Midlands

** Results from previous years information. For 1983 isolates, data are from seedling differential tests only.

RESULTS

Seedling tests with 1984 isolates.

Sampling was not carried out on a random basis and virulence frequencies shown for 1976-84 (Table 3) should therefore be interpreted with caution. In 1984 WYV 2 and WYV 3 remained at 100%. All isolates which possessed WYV 9 also possessed WYV 1. Most of the WYV 1,9 isolates had been collected on the NIAB trial ground from cultivars possessing WYR 9 or WYR 0, but not WYR 1,9. This indicates that the WYV 1,9 combination survives well in the pathogen population and could rapidly become widespread. The frequency of WYV 6 was twice that detected in previous years, due mainly to the large proportion of samples received from crops of Longbow (WYR 1,2,6). Six isolates were virulent on Boxer. Three of these possessed WYV 2,3,4,6 and three WYV 1,2,3,9.

Table 3 Virulence factor frequency (%)

WYV Factor		1976	1977	1978	1979	1980	1981	1982	1983	1984
WYV 1	Chinese 166	92	73	73	83	95	71	63	85	75
WYV 2	Heine VII	100	100	97	100	100	100	100	100	100
WYV 3	Vilmorin 23	100	100	100	100	85	95	100	100	100
WYV 4	Hybrid 46	12	24	27	17	15	29	37	20	31
WYV 5	T. spelta album	0	0	0	0	0	0	0	0	0
WYV 6	Heine Kolben	4	16	26	17	25	31	29	26	64
WYV 7	Lee	0	8	0	0	0	5	5	0	3
WYV 8	Compair	2	4	0	0	0	0	2	0	0
WYV 9	Riebesel 47/51	6	0	0	0	0	5	2	23	31
WYV 10	Moro	0	0	0	0	0	0	0	0	0
Additional test cultivars-1984										
	Fenman									3
	Brimstone									3
	Boxer									17
Number of isolates tested		52	26	26	30	20	42	41	63	36

One isolate (84/1) was received from adult plants of the cultivar Brimstone, which had been inoculated with an isolate possessing virulence for seedlings of Brimstone. Tests showed that 84/1 possessed the unusual virulence combination WYV 1,4, together with WYV 2 and WYV 6, and was the only isolate virulent on both Fenman and Brimstone in seedling tests. WYV 1,4 has been detected sporadically in Survey samples (two samples in 1976, two in 1980 and three in 1983). Two similar isolates have been reported by Johnson (1976, 1977), originating from inoculated and naturally infected crops of Maris Templar. WYV 1,4 has also been detected fairly readily in laboratory hybridisation experiments involving isolate mixtures (Goddard 1976, Taylor, 1976).

During 1984, a number of re-isolates were made from inoculated plots of Brimstone and other cultivars in NIAB Polythene tunnel tests. Four of these were found to possess WYV 1,4, although this virulence combination had usually been absent from the initial inoculumn. Seedling differential tests indicated that the WYV 1,4 isolates differed in their ability to infect Brimstone, Fenman and WYR 2 and WYR 6 differential cultivars. Consequently, they were tested on additional cultivars possessing relevant WYR factors. (Table 4).

Table 4. Average infection types* on seedlings of wheat cultivars possessing WYR 1, WYR 2, WYR 4 and WYR 6 alone and in different combinations when inoculated with isolates possessing WYV 1,4.

		Isolate and WYV Factors				
		84/A4	84/1	84/A5	84/A11	77/26R2
		1,(2),4,6	1,2,4,6	1,2,4	1,2,4	1,2,4
Test Cultivars	Seedling WYR Factors					
Hustler	1	3.7	4.0	3.9	4.0	2.7
Maris Templar	1	4.0	4.0	3.0	4.0	4.0
Avalon	4	3.0	4.0	3.0	4.0	4.0
Iona	1,4	2.9	4.0	3.6	3.4	2.0
Maris Beacon	4(+2?)	1.4	3.9	4.0	4.0	4.0
Maris Huntsman	2	1.8	3.7	4.0	3.4	3.6
Longbow	1,2,6	1.6	4.0	0.0	0.0	0.0
Maris Ranger	6	3.0	3.7	0.0	1.0	0.0
Brimstone	1,4≠	3.0	4.0	3.0	4.0	4.0
Fenman	1,2,4≠	0.9	3.0	3.5	4.0	3.7

* Average infection types $\geq$ 2.0 are regarded as susceptible, those $<$ 2.0 as resistant.

≠ Proposed seedling WYR factors.

	Source of isolates	
Isolate	Cultivar	Inoculated isolate:-
84/1	Brimstone	P81/10 (WYV 1,2,4,6)
84/A4	Avalon	P631 (WYV 1,2,(4)(6),7)
84/A5	Brimstone	P75/27 (WYV 2,4,14)
84/A11	Brimstone	P75/27R (WYV 2,4,14)
77/26R2	Galahad	77/26 (WYV 1,2,14)

The results indicate that Brimstone and Fenman differ in their susceptibility to isolates possessing WYV 1,4. Fenman was susceptible to all isolates except 84/A4, which was also largely avirulent on cultivars possessing WYR 2 (Gawain, Maris Huntsman, Maris Beacon, Longbow). In contrast, Brimstone was susceptible to all isolates. WYV 6 was unnecessary for virulence on Brimstone or Fenman. It is concluded that Fenman possesses the resistance factors WYR 1,2,4 and Brimstone WYR 1,4.

The scarcity of WYV 1,4 in Survey samples may be due to the absence of selection pressure from WYR 1,4 cultivars, and the possibility that WYV 1,4 isolates may be relatively uncompetitive.

Adult Plant tests with 1983 and control isolates

Adult plant infection data, together with the specific resistances identified in cultivars to date and the specific virulences identified in isolates, are presented in Table 5. 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. In the discussion which follows, we have concentrated on new information emerging from the 1984 results. Results for those cultivars and isolates not specifically mentioned are consistent with the previously established identifications of resistance and virulence listed in the table.

Cultivars which showed a high degree of resistance to all isolates as adult plants differed in their seedling reactions. This group included Boxer, which was tested for the first time in 1984.

The eight cultivars listed from Avalon to Moulin interacted with WYV 14 isolates. Avalon interacted with isolates possessing WYV 4,14 (Box A). This, together with the fact that Avalon was resistant to isolate 81/34 (possessing WYV 4 but lacking WYV 14), provides firmer evidence than previously available that the cultivar possesses the resistance combination WYR 4,14.

Rapier, Brigand and Gawain interacted with isolates possessing WYV 2,4,14 (Box B). It is apparent from seedling reactions that Rapier possesses the overall resistances WYR 2,4 in addition to the adult plant resistance WYR 14, whereas Brigand and Gawain possess only the overall resistance WYR 2 in combination with WYR 14.

Galahad, which possesses the overall resistance WYR 1, showed an increased level of infection with the WYV 1,14 isolate P79/4 confirming the identification of its resistance as WYR 1,14. However, the level of infection was considerably lower than expected from 1983 results and reflected the generally low levels of infection produced by P79/4 in 1984.

Moulin interacted markedly with isolates possessing WYV 6,14 (Box C) providing clearer evidence than previously that the variety possesses WYR 6,14. Other WYR 6 cultivars interacted with isolates in Boxes D, E and F. Longbow showed an appreciably higher level of infection with 83/62 than with 83/A3, as did the WYR 13 cultivars Maris Huntsman, Hustler and Virtue, indicating that Longbow may possess WYR 13 in addition to WYR 1,2,6.

Cultivars possessing WYR 9 interacted with isolates in Boxes H, J and K. Stuart and Hammer showed higher levels of infection with WYV 1,9 isolates than with the WYV 4,9 isolate, but were susceptible to both types at the seedling stage suggesting that, as observed in 1983, WYR 1, or some other unidentified specific resistance, is effective in adult plants of these cultivars.

Stetson was as susceptible as Clement to each of the four 1983 isolates which possessed WYV 1,9, although the original Stetson virulent isolate (82/29) gave markedly less infection on Stetson than Clement in both 1983 and 1984. This may represent increased virulence compatible with the resistance factors of Stetson. There is some indication that those isolates most virulent on Stetson were also virulent on WYR 13 cultivars (Box G).

Cultivars possessing WYR 7 interacted with isolates in Box L. Renard was uninfected by 71/493, although it had exhibited similar infection levels to Brock with the same isolate in 1983 tests.

Seven Survey isolates were tested for the first time in Polythene tunnels during 1984. Three of these were WYV 1,9 isolates, which also appeared to give increased infection on WYR 13 cultivars as discussed above. However, the reaction of the WYR 13 cultivars was somewhat inconsistent and no firm conclusion can be drawn on the existence of isolates possessing WYV 9,13. Combined virulence for WYR 9 and an adult plant resistance has not previously been detected in Survey samples.

Isolate 83/96, a Survey isolate collected from Moulin, interacted with WYR 13 and WYR 14 cultivars in a similar way to P81/12. This is the first Survey isolate in which combined adult plant virulence has been detected. Such combinations, if they became common, could limit the scope for cultivar diversification.

Isolates 83/28 and 83/53 proved to be WYV 1,2,3,13 and 83/62 possessed WYV 1,2,3,6,13 with increased virulence for Longbow as previously noted.

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Table 5 Results of Adult Plant tests 1984

Values are percent leaf area infection (mean of four assessment dates). Identifications of WYR and WYV factors are based not only on results presented here, but also on others reported previously.

Boxes are used to mark apparent cultivar x isolate interactions in adult plant tests, and have no statistical significance. Letters in boxes are for text reference only.

Underlined figures indicate a susceptible reaction in seedling tests (type > 2.0). Figures not underlined indicate a resistant reaction (type 0-2).

( ) = partial virulence

APR = adult plant resistance

* = WYR factors identified subsequent to main seedling test.

** = previous evidence shows that Cappelle Desprez possess WYR 3. Since all recent test isolates have possessed the corresponding virulence WYV 3, the possibility that other cultivars possess WYR 3 cannot be precluded.

Table 5. Results of Adult Plant Tests 1984

Cultivar	WYR Factors	Isolate and WYV Factors	P79/4 1,2,3,14	P75/27R 2,3,4,14	P75/27 2,3,4,14	83/96 2,3,4,6,13,14	P81/12 2,3,4,6,12, 13,14	P81/20 3,4,6,14
Aquila	Rx		0	0	1	0	1	0
Boxer	Rx		0	0	0	0	0	0
Brimstone	1,4*		0	1	0	0	0	0
Fenman	1,2,4 *		0	0	1	0	0	0
Mission	4		0	0	0	0	0	0
Maris Beacon	4(?+2)		0	10	26	17	12	1
Avalon	4.14		0	6	10	A 6	6	7
Rapier	2,4,14		0	4	13	8	9	0
Brigand	2,14		4	8	12	B 16	11	0
Gawain	2,14		4	7	12	10	10	0
Hobbit	14		6	10	17	8	11	14
Bilbo	14		13	21	33	21	22	26
Galahad	1,14		2	0	0	0	0	0
Moulin	6,14		0	2	2	8	9 C	14
Freeman	6		0	0	1	11	10	14
Maris Ranger	6		0	2	1	11	11	14
Kinsman	6		0	2	0	16	16	10
Norman	2,6		0	0	0	10 E	10	0
Longbow	1,2,6 (?+13)		0	0	0	0	0	0
Maris Huntsman	2,13		3	5	6	11	7	0
Hustler	1,13		2	0	0	5	0	0
Virtue	1,13		3	1	1	4	0	0
Armada	12		0	0	0	3	4	2
Mega	12		0	0	0	2	6	2
Baron	9 + APR		0	0	0	0	0	0
Abele	9 + APR		0	0	0	0	0	0
Stuart	9 + APR		0	0	0	0	0	0
Hammer	9 + APR		0	0	0	0	0	0
Stetson	1,9		0	0	0	2	0	0
Clement	9		0	1	0	0	0	0
Renard	7		0	0	0	0	0	0
Brock	7		0	0	0	0	0	0
Tommy	7		0	0	0	0	0	1
Maris Templar	1		7	2	3	1	0	0
Cappelle Desprez	3 **		4	6	10	7	6	7
Michigan Amber	0		9	16	21	24	11	14

83/A3	23/62	76/71	76/71R	83/28	83/53	71/493	P631	81/34	82/29	83/39	83/44	83/10
1,2,3,6	1,2,3,6,13	1,2,3,13	1,2,3,13	1,2,3,13	1,2,3,13	1,2,3,7	1,2,3,(4),(6),7	2,3,4,9	1,2,3,9	1,2,3,9,? 13	1,2,3,9,? 13	1,2,3,9,? 13
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	0	0	0	0	0	0	0
0	2	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0	0
2	3	0	0	1	1	1	1	7	2	1	0	1
1	0	0	0	0	0	0	0	0	0	0	1	0
1	0	0	0	0	0	0	1	0	0	0	0	0
4	4	3	4	6	5	3	2	1	5	3	0	4
16	6	1	1	7	16	12	1	1	10	2	3	5
2	3	0	0	1	1	1	1	0	1	1	2	1
12	10	7	8	10	12	14	9	14	9	16	16	8
1	1	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0
12	8	0	0	0	1	0	2	0	0	0	1	1
13	10	0	0	1	1	0	6	0	1	1	0	0
11	17	1	1	0	3	0	5	1	3	1	1	0
13 E	15	0	0	0	1	0	1	0	1	0	2	0
9 F	15	0	0	1	1	0	0	0	0	0	0	0
6	19	9	9	13	9	2	2	2	5	10	5	8
5	13	9	10	12	13	1	2	0	2	7	14 G	15
9	16	9	10	13	13	16	15	0	5	6	12	10
0	0	0	0	1	0	0	0	0	0	0	0	0
1	1	1	1	0	1	1	1	1	1	1	0	1
0	0	0	0	0	0	0	0	0	1	1	0	1
0	0	0	0	0	0	0	0	0	1	3	1	2
0	2	0	0	0	1	0	0	3	9	20 H	12	15
0	0	0	0	0	0	0	0	1	7	6	4	9
1	1	1	2	1	1	0	0	0	13	33 J	29	34
2	2	0	3	0	2	0	2	10	32	28 K	35	35
0	0	0	0	0	0	0	2	0	0	0	0	0
0	0	0	0	0	0	5	2	0	0	0	0	0
2	0	0	0	0	0	14 L	10	0	2	0	0	1
8	10	10	16	11	12	6	9	0	9	10	6	9
11	7	7	8	5	7	8	3	0	8	6	9	8
13	18	5	8	6	10	10	9	4	7	10	6	14

BROWN RUST OF WHEAT

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The isolates of Puccinia recondita cultured from the four leaf samples of wheat brown rust received in 1984 were tested on seedlings of the differential cultivars under both a low and a high temperature regime. The winter cvs Brock and Renard and the Thatcher isoline carrying Lr3Ka gave a pattern of response similar to the WBR-2 cultivars Maris Fundin, Norman and Hobbit. The resistance of cv. Sappo (WBR-3) appears to be present in the spring wheat cvs Sicco, Timmo, Solitaire and Wembley. Resistance that is expressed only at a high or low temperature was observed in several of the differential cultivars. The adult plant, temperature-sensitive resistance of cvs Virtue, Hustler and Rapier remained effective in field isolation nurseries. The resistance of the winter cvs Gawain, Moulin and Brimstone and of the spring cv. Axona, which appears to be of the adult plant type, was also effective to the four isolates tested in the field. The resistance of the spring cv. Jerico seems to be of the overall type. Isolate WBRS-83-11H gave higher levels of infection than had previously been observed on cv. Maris Ranger. 'Reception nurseries' were again sown in 1984 to allow earlier identification of increased virulence to cultivars possessing adult plant resistance.

SEEDLING TESTS WITH 1984 ISOLATES

Only four samples were received in 1984. They included a sample from cv. Virtue with only 0.1% infection from a trial site at Seale-Hayne, Devon. The remaining samples from cvs Avalon, Armada and Galahad were all from trial sites in the east of England.

The isolates 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 Dr R.A. MacIntosh, Australia (Clifford & Jones, 1984). The winter wheat cvs Moulin, Mission, Hammer, Galahad, Stetson, Gawain, Brock, Renard, Boxer and Brimstone together with the spring wheat cvs Minaret, Musket, Sicco, Timmo, Axona, Jerico, Solitaire, Tonic and Wembley 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

Isolates of Puccinia recondita were cultured from the 4 leaf samples. Virulence to WBR-1 in cv. Clement, which is derived from rye, was not detected in any of the isolates. Cvs Stetson and Hammer which carry the same resistance were also resistant.

The temperature-sensitive resistance WBR-2, present in cvs Maris Fundin, Norman and Hobbit, was effective against two of the isolates. The winter cvs Brock and Renard, the Thatcher line Lr3Ka, and the R.A.M. line Tc + Lr 30 (Lr T) (Lr 30) also gave the same pattern of response.

Isolates WBRS-84-1 and WBRS-84-3 gave a mixed resistant reaction on cvs Sappo (WBR-3) and Maris Halberd (WBR-4) at the lower temperature regime, but were compatible at the higher temperature regime, thus confirming the temperature-sensitive resistance of these two cultivars. A similar pattern of response occurred in the spring wheat cvs Sicco, Timmo, Solitaire and Wembley, and in the R.A.M. line Thew (Lr 20). Cv. Gamin (WBR-6) was susceptible to the 4 isolates tested. The resistance of cv. Sterna (WBR-7) and cv. Sabre was not overcome at either temperature.

In the Thatcher Lr backcross lines, resistance conferred by Lr 2a was effective against all 4 isolates at 10°C, but only to two isolates at the higher temperature. The converse was true of Lr 15 to the same two isolates.

THE R.A.M. lines Gatcher (Lr 27) and CS 70 Ag#11 (Lr 29) expressed a resistant reaction at 10°C but not at 25°C.

The winter cvs Gawain, Galahad, Moulin, Mission, Boxer and Brimstone, and the spring cvs Axona, Minaret, Musket and Tonic were susceptible to the 4 isolates at both temperature regimes.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Four isolates were tested on adult plants in field isolation nurseries in 1984. The isolates used were:

Isolate	Origin and description
WBRS-83-11 V	Cv. Avalon, Cambridge. Isolate sub-cultured from cv. Virtue inoculated with isolate WBRS-83-11 (Clifford & Jones, 1984)
WBRS-83-11 H	Cv. Avalon, Cambridge. Isolate sub-cultured from cv. Hustler inoculated with isolate WBRS-83-11 (Clifford & Jones, 1984).
WBRS-83-50	Cv. Rapier, Kent. Rapier-virulent at 10°C in adult plant tests under a controlled environment.
WBRS-74-2	Cv. Maris Huntsman, Morley. Huntsman-virulent.

Each nursery comprised 36 winter and 10 spring wheat cultivars, replicated 3 times. Assessments of percentage infection and reaction type were made throughout the season.

Results

These are summarised in Table 1. Results confirmed the previous grouping of cultivars according to their resistance factors. Cv. Maris Ranger (WBRS-8) which possesses an adult plant resistance (Clifford et al., 1981) was highly susceptible to isolate WBRS-83-11H. Previously, isolates carrying specific virulence to this cultivar had only given low levels of infection. Cv. Kinsman resembled cv. Maris Ranger in its response to the four isolates. Similarites between these two cultivars in their reactions to isolate WBRS-77-9 has previously been observed (Bayles & Priestley, 1983).

Cvs Galahad and Longbow again displayed similar levels of infection, although these cultivars have been differentated on their interactions with isolates WBRS-80-1 in polythene-tunnel tests at the NIAB, Cambridge (Bayles & Priestley, 1983, 1984).

The adult plant, temperature-sensitive resistance of cvs Virtue and Hustler gave a mixed, generally resistant reaction to isolates WBRS-83-11H and WBRS-83-11V although quantitatively, cv. Virtue was less resistant to its own isolate. Cv. Rapier, which has a similar type of resistance, was resistant to all isolates including WBRS-83-50 which had shown some compatibility with this cultivar at the low temperature regime in the 1983 reception nursery tests.

The resistance of the winter wheat cvs Gawain, Moulin and Brimstone was effective against all isolates, as was that of the spring cvs Jerico, Broom and Axona.

ADULT PLANT RECEPTION NURSERIES

Wheat 'reception nurseries' were again sown at WPBS in 1984 to monitor increased virulence to adult plant resistances and to determine the effect of temperature on the wheat:rust interaction. Cultivars tested were:

Virtue	(Adult plant, temperature-sensitive resistance. Virulence previously not detected in field isolation nurseries)
Hustler	(" " " " " ")
Rapier	(" " " " " ")
Moulin	(" " " " " ")
Avalon	(Adult plant resistant. Virulence detected in 1980)
Kinsman	(Adult plant resistant)
Armada	(Susceptible check)

Isolates tested were cultured from the 4 samples of P.recondita received in the 1984 UK CPVS. Because of the high levels of infection on cv. Maris Ranger within the field isolation nursery inoculated with isolate WBRS-83-11H, this isolate, together with isolate WBRS-83-11V, was also tested on adult plants in controlled environments giving temperature regimes of either 10° or 25°C. Cv. Maris Ranger was included in tests with these two isolates.

Results

Assessments of reaction type and percentage infection were made on the flag leaf, 8 days and 14 days after inoculation at the high temperature regime and 18 and 24 days after inoculation of the lower temperature. Results and isolates tested are summarised in Table 2.

The temperature-sensitive resistance of cv. Virtue was confirmed as seen from the reaction with isolate WBRS-84-4 which was derived from cv. Armada. Isolate WBRS-83-11V gave an indication of some increase in compatibility on cv. Virtue at the lower temperature and there was a similar response in the field test of this isolate (see Table 1). The 1984 field isolate from cv. Virtue, namely WBRS-84-1, was compatible with cv. Virtue at the low and the high temperature. This isolate will be further evaluated in field isolation nurseries in 1985. Virulence to cv. Avalon was confirmed in the cv. Avalon field isolate WBRS-84-2 and this virulence must now be considered common in the field population of P.recondita. The isolate WBRS-83-11H, sub-cultured from cv. Hustler, failed to show increased compatibility with cv. Hustler and this confirms the 1984 field test (Table 1). However, this isolate did show increased compatibility on cv. Kinsman, a cultivar which expressed low (10°) temperature resistance of the adult plant type to the five other isolates tested. An anamolous and unexplained result was the low infection obtained on cv. Avalon when tested with isolate WBRS-84-1 at 25°C. These results generally confirm the resistance of the test cultivars and indicate specific virulences to them. They also confirm the importance of controlled tests using defined environments, host and pathogen genotypes for reasonable interpretation of results to be made. Specific interactions show quantitative variation in expression which may be due to the environment, particularly with regard to temperature, the growth stage of the host and the genetic configuration of both host and pathogen genotype. Temperature-sensitivity of resistance is now clearly demonstrated and there is also evidence of temperature-sensitivity of virulence expression in the pathogen (Clifford, unpublished).

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Table 1. Adult plant field reactions of wheat cultivars to specific isolates of Puccinia recondita tested in field isolation nurseries at WPBS in 1984

Cultivar	WBR factor	Isolate WBRS-83-11V $\bar{x}$ (%)	WBRS-83-11H $\bar{x}$ (%)	WBRS-83-50 $\bar{x}$ (%)	WBRS-74-2 $\bar{x}$ (%)
Clement	1	8	43	3	4
Aquila	(1)	8	41	3	1
Stetson	1	10	49	2	3
Hammer	1	6	29MS	2	2
Fundin	2	38	33	25	18
Sentry	2	22	27	13	13
Norman	2	21MS	16MS	6	6MS
Hobbit	2	22MS	20MS	6	3
Sappo*	3	3	5	8	3
Halberd*	4	7	5	3	3
Huntsman	5	21MS	28	10	30
Brigand	5	24MS	21	10	29
Mardler	5	20MS	28MS	3MS	22
Gamin	6	25	28	22	6
Sabre	7	Trace	Trace	0	0
Sterna	7	0	3	0	0
Maris Ranger	8	5	33	4	1
Kinsman	8?	7MS	23MS	2MS	Trace MS
Avalon	9	44	40	23	20
Sportsman	9	33	41	24	9
Bounty	9	33	34	17	13
Moulin		5MR	3	1	Trace R
Hustler		3MS	0.5MR	Trace	Trace
Virtue		13MR	3MR	2	Trace
Gawain		12MR	7MR	4MS	1
Brimstone		7MR	2MS	Trace MS	0
Rapier		0	0	0	0
Jerico*		0	0	0	0
Broom*		Trace R	Trace R	0	0
Axona*		Trace R	0	0	0
Renard		44	43	19	14
Brock		42	31	22	11
Boxer		33	37	13	5
Armada		33	42	16	18
Mission		32	36	12	16
Flanders		23	37	17	17
Fenman		23	29	10	13
Galahad		25	26MS	8	16
Longbow		19MS	24MS	5	21
Musket*		11	7	4	4
Tonic*		11	5	3	3
Solitaire*		12	3	3	1
Sicco*		10	5	3	1
Timmo*		9	8	5	3
Minaret*		7	7	4	2
Wembley*		5	3	2	1

* = Spring cultivars
Winter cultivars = $\bar{x}$ of 2 assessment dates, 3 replicates
Spring cultivars = $\bar{x}$ of 1 assessment dates, 3 replicates

Table 2. Results of adult plant tests in wheat reception nurseries to selected isolates of P.recondita

	Origin of Isolate											
	WBRS-84-1 ex Virtue		WBRS-84-2 ex Avalon		WBRS-84-3 ex Galahad		WBRS-84-4 ex Armada		WBRS-83-11V ex Virtue*		WBRS-83-11H ex Hustler*	
Test cultivar	L	H	L	H	L	H	L	H	L	H	L	H
Virtue	35MS	43	20MS	13MS	20MR	5	15MR	20	21MR	20MS	4MS	14
Hustler	26MR	10MR	6MR	10MS	5MR	8	18MR	9	2MS	10MS	3MS	3MR
Rapier	24MR	34	0	18	0	2	0	4R	0	14	0	7
Avalon	39	5	43	30	9	19	25	40	6	18	19	18
Armada	20	31	34	10	35	28	45	38	26	22	51	9
Kinsman	19R	38	13R	20	15MR	24	35MR	25	3	24MS	28MS	27MS
Moulin	9MS	13MS	19MR	2MS	0	2	0	0	-	3	0	2MR
Ranger	-	-	-	-	-	-	-	-	0	3	7MS	17

L = Low temperature regime; H = high temperature regime; R = resistant; MS = mixed susceptible; MR = mixed resistant;
Each value = % level of infection, mean of 2 scoring dates and 2 replicates

All reaction types susceptible unless indicated
*1 = sub-sample from cv. Virtue inoculated with WBRS-83-11 ex Avalon
*2 = " " " cv. Hustler " " "

BROWN RUST OF WHEAT TESTS AT NIAB

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Three isolates of Puccinia recondita (83/7, 83/86 and 83/87), which had been virulent on adult plants of cultivars Hustler, Rapier and Virtue in controlled environment tests, were found to be avirulent on these cultivars in Polythene tunnel tests.

INTRODUCTION

The main aim of 1984 tests was to determine whether the virulence for adult plants of cultivars Hustler, Rapier and Virtue detected in controlled environment tests at high and low temperature regimes (Clifford and Jones 1984) could be confirmed in Polythene tunnels.

METHODS

Five isolates supplied by the WPBS were tested on seedlings and adult plants of 31 winter wheat cultivars. Details of the isolates used are given in Table 1. Seedling tests were carried out in controlled environment chambers (16hr day at 11°C, 8 hr night at 11°C). Adult plant tests were carried out in Polythene tunnels. Two replicate tussocks were sown on 24th-25th November, inoculated on 28th March and 10th April, and assessed for percentage leaf area infection on 3rd May (GS 32), 11th May (GS 38), 22nd May (GS 45), 4th June (GS 52) and 14th June (GS 68).

Table 1. Isolates used in adult plant tests

Code	Cultivar	Site	Region*	WBV Factors
80/1	Brigand	WPBS	?	WBV 1,2,5
80/21	Avalon	Rosemaund	WM	WBV 2,9
83/7	Avalon	Didcot	SE	WBV 2,9
83/86	Rapier	Taunton	SW	WBV 2,9
83/87	Virtue	Cambridge	E	WBV 2,9

*WM = West Midlands, SE = South East, SW = South West, E = East
All isolates originally supplied by WPBS.

RESULTS

Infection levels on adult plants and seedling reactions in 1984 are given in Table 2, together with corresponding results for the same isolates in 1981, 1982 and 1983. Isolate 80/1 interacted with WBR 1 and WBR 5 cultivars (Boxes A and B), but appeared less aggressive on M Huntsman and Longbow than in previous years. It was markedly more aggressive on M Bilbo, and also produced low levels of infection on Avalon and Bounty indicating some contamination with WBV 9.

M. Bilbo has previously been classified as a WBR 2 cultivar on the basis of seedling reactions, although as an adult plant it has been more susceptible

to WBV 2,9 isolates than WBV 1,2,5 isolates, suggesting that it also possesses WBR 9 (Box C).

Isolates 83/7, 83/86 and 83/87 proved similar to 80/21 interacting with Avalon and Bounty (Box D). They did not infect Hustler, Rapier or Virtue and it therefore appears that the susceptibility of these cultivars observed in the artificial environments described by Clifford and Jones (1984) is not expressed in the Polythene tunnel environment.

Isolate 83/87 produced a small number of type 4 pustules on seedlings of WBR 1 cultivars, and a low level of adult plant infection on some WBR 1 cultivars. This probably reflects a low level of WBV 1 contamination rather than a combination of WBV 1 and 9.

Five cultivars, Boxer, Brock, Brimstone, Gawain and Renard were included in tests for the first time in 1984. None showed any obvious interactions with the isolates used.

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Table 2. Results of 1984 adult plant and seedling tests, compared with the same isolates tested in 1981, 1982 and 1983.

Values are mean percent leaf area infection (mean of 5 assessment dates in 1984). Data for 1980 have been omitted because of poor infection in polythene tunnels.

	Isolate	80/1				80/21			83/7	83/86	83/87
	WBV Factors	1,2,5+				2,9			2,9	2,9	2,9
	Year of test	81	82	83	84	82	83	84	84	84	84
WBR Factor	Cultivar										
WBR 1	Clement	20	6	18	9	0*	1	3*	0*	0*	4
	Stuart	6	3	9	3	0*	0*	0*	0*	0*	1
	Stetson	–	1	11	1	0*	1*	0*	0*	0	1
	≠ Aquila	5	4	4	1	0	0	0	0	0	0
WBR 1+	Abele	8	3	10	2	0*	0*	2*	0*	0*	0
	Baron	9	16	23	8	0*	2*	0*	0*	0*	0
	Hammer	–	–	12	8	–	0*	0*	0*	0*	0
WBR 2	M Fundin	8	3	14	7	27	11	16	10	13	8
WBR 2 (?+9)	M Bilbo	1	1	1	17	26	19	17	17	14	15
WBR 2+	Hobbit	4	1	3	1	0	0	0	0	0	0
	Norman	4	4	6	2	0	0	1	0	1	0
WBR 5	M Huntsman	12	7	16	6	1	0	0	0	0	0
	Brigand	2	1	7	2	2	0	1	1	1	2
	Mardler	7	–	–	2	–	–	0	0	1	0
	Longbow	7	6	17	3	0	0	0	0	0	0
WBR 8	M Ranger	–	0	–	1	0	–	0	0	1	1
WBR 9	Avalon	0*	0*	0*	5*	40	10	11	6	12	14
	Bounty	0	0	0	5	13	3	8	7	7	6
	Brimstone	–	–	–	0	–	–	0	0	0	0
	Hustler	0	0	0	0	0	0	0	0	0	0
	Rapier	0	0	0	0	0	0	0	0	0	0
	Virtue	0*	0	0*	0	0	0	0	0	0	0
	Moulin	–	–	0*	0	–	0	0	0	0	0
	Galahad	–	0	0*	2	0	0	0	0	0	0
	Gawain	–	–	–	0	–	–	1	0	1	0
	Boxer	–	–	–	3	–	–	3	5	4	4
	Fenman	4	3	8	4	4	5	3	4	7	4
	Mission	–	–	3	4	–	2	11	5	9	6
	Armada	8	3	4	7	13	3	8	11	7	15
	Renard	–	–	–	6	–	–	12	11	8	15
	Brock	–	–	–	14	–	–	12	12	15	13

A, B, C, D

* = resistant reaction (type 0.0-2.0) in seedling tests.

≠ = specific resistance expressed at adult plant stage, and probably differing genetically from that of other WBR 1 cultivars.

Boxes are used to mark apparent cultivar x isolate interactions and have no statistical significance. Broken lines mark interactions suspected to be due to isolate contaminatio

Letters in boxes are for text reference only.

MILDEW OF BARLEY

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No new pathogenicity characters were found, but several novel combinations were identified among pathogen isolates. New resistance combinations were identified in the host, a number of which included M1Ab, the second resistance gene in cv. Triumph (M1a7 + M1Ab). There was evidence of an increasing range of resistance genes from spring barleys among the new winter barley cultivars. Pathogenicity for cv. Triumph predominated in England and increased in Scotland. On the other hand, pathogenicity for BMR 4 and 5 continued to decrease in frequency.

Low levels of insensitivity to the triazole fungicides were common throughout England and Scotland, and higher levels increased in frequency in eastern England. There was some evidence of insensitivity to ethirimol and tridemorph, particularly in Scotland. The levels were similar in fractions of the pathogen population more or less insensitive to the triazoles.

Accumulated data from the static nursery exposed regularly on the roof of the Botany School in Cambridge, indicated that there were six phases of epidemic change during the year. It was evident that the overall decline in BMV 4 was tempered by relatively greater survival during the winter of this character compared with the other pathogenicity characters.

No new resistance genes were found, but several novel combination were identified (Table 1). More of the new winter barleys have resistance genes derived from spring cultivars, for example, cv. Nevada has M1g combined with the winter barley resistance from W. 37/136, cv. Kaskade has M1al2 combined with the winter barley resistance from W. 41/145, and cv. Natalie has M1k/a7 combined with both of the winter barley resistances.

An isolate obtained from cv. Triumph was pathogenic on cv. Triumph, cv. Tasman and cv. Porter, but not on the differential HOR 1063 (M1k), confirming that, unlike many lines with resistance derived from cv. Lyallpur 3645, these cultivars possess M1a7 but not M1k. Cv. Triumph and cv. Tasman also possess M1Ab, derived from Abl2, an Ethiopian line, but cv. Porter has only M1a7. Cultivars are also now beginning to emerge with M1Ab combined with resistance genes other than M1a7 at the M1a locus, for example, cv. Tavern (M1Ab + M1al), cv. Rhapsody (M1Ab + M1a6) and cvs. Acclaim and Natasha (M1Ab + M1al2).

Pathogen population structure

Population samples obtained from leaves (total of 88 samples) and from the stick sampler (total of 150 samples) in plots of individual cultivars at NIAB regional trial centres were tested and compared for their ability to attack the cultivar from which they were obtained (corresponding pathogenicity) and other cultivars of current importance (non-corresponding pathogenicity). Values for corresponding and non-corresponding pathogenicity among the leaf samples for BMR groups are in Table 2; they followed the pattern observed in previous years. For example, BMV 2 and 3 were frequent in most populations and BMV 6+Ab was more frequent in populations on the winter barley cultivars than elsewhere. BMV 4 was relatively uncommon on BMR 6 and 6+Ab, as were BMV 6 and 6+Ab on BMR 4. Similarly, BMV 5 had a low value in populations from BMR 6 and 6+Ab, and the converse was also true. The newly selected BMV 8 population on Kym was infrequent on all cultivars lacking BMR 8.

Table 1. Number of samples received in 1984 and the BMR group definitions of the cultivars from which they were collected

BMR group	Gene	Cultivar and number of samples
0	-	Maris Otter (4 untreated, 1 Baytan treated, 11 treated with Baytan and Bayleton, 4 treated with Baytan, Bayleton and Tilt Turbo, Halcyon (6 untreated, 1 Baytan trt.), Impact(2), Gold. Promise(1)
1b	M1(41/145)	Igri (3 untreated, 3 Baytan treated), Gerbel (3), Metro (3), Sonja (3), Monix (2), Flamenco (2), Libra* (2), Opera* (2)
1a+b	M1h+M1(41/145)	Pirate (3), Athene (2)
5	M1a12	Beauly* (-)
6	M1+M1a7	Donan* (-)
7	M1a1	Delta (4), Matelot* (-)
8	M1k+M1a9	Roland* (6)
1a+2	M1h+M1g	Nevada* (3), Panda (2 untreated, 2 Baytan treated, 1 treated with mbc/prochloraz)
1b+2	M1(41/145)+M1g	Tipper (2)
1b+5		Kaskade* (3)
2+4	M1g+M1v	Golf (4), Koru (4), Candice* (-)
2+5		Themis* (8), Patty (4)
2+8		Efron* (5)
3+4	M1a6+M1v	Goldmarker (1), Laser* (-)
4+5		Egmont (1)
4+6		Klaxon (4), Doublet* (3)
4+7**		Vista* (7)
4+8		Kym (8), Cameo* (-)
4+mlo		Atem (4)
5+Ab**		Acclaim* (3), Natasha* (7)
6+Ab	M1a7+M1Ab	Triumph (5 unt., 1 Baytan tr.), Tasman(4)
7+Ab**		Tavern* (-)
1a+1b+2+6		Natalie* (3)
mlo+?		Apex (3)

* new identifications in 1984
** new group identification

Table 2. Corresponding and non-corresponding pathogenicity in samples from BMR group cultivars at NIAB regional centres

BMR source	BMV character 2	3	4	5	6	6+Ab	4+8
0 (9)*	46	52	13	19	54	55	1
1b (18)	44	47	15	14	45	48	2
1a+b (5)	50	57	9	6	74	68	1
1a+2 (6)	41	45	5	6	54	57	0
1b+2 (2)	72	59	30	14	23	40	0
4+2 (4)	59	35	57	24	0	3	0
4+7 (4)	90	36	57	39	0	1	8
4+mlo (1)	83	95	82	76	0	0	0
5+1b (3)	47	42	27	66	0	1	2
5+2 (6)	42	21	28	44	6	3	5
5+Ab (3)	56	36	14	43	18	21	0
5+Na (4)	62	32	29	47	8	14	4
6+1a+ 1b+2 (3)	53	63	0	0	80	73	0
6+Ab (6)	44	30	0	0	67	76	0
7 (2)	51	10	38	5	15	2	0
8 (4)	54	30	29	29	24	2	42
2+8 (2)	186	65	4	0	16	16	8
4+6 (5)	56	22	28	9	73	49	7
4+8 (1)	73	7	75	5	51	3	91
mean non-corresp.	59	41	16	16	26	27	2

* denotes no. of bulk isolates

The mean values obtained by the two methods (Table 3) showed that the stick sampler gave relatively lower values for corresponding pathogenicity, in most cases, although both methods were similar for non-corresponding pathogenicity. The difference might have been due to a relatively high proportion of migrant spores caught in the stick sampler, which would not necessarily be able to establish on host leaves in a particular plot. This indicates that the pathogen population established on cultivars in trials may differ qualitatively and quantitatively from those established on the same cultivars on a field scale. If so, then the disease resistance and yield of a cultivar may be, to some extent, a function of the way in which the cultivar is grown. Much further work is needed to establish the importance of this point.

Table 3. Means of corresponding and non-corresponding pathogenicity in samples from BMR cultivars at NIAB regional centres, collected as leaf samples or in the stick sampler

Source	BMV character 2	3	4	5	6	6+Ab	4+8
Corr. path.							
lf. samples	76	-	60	45	73	76	47
stick samples	55	-	33	53	54	44	22
Non-corr. path.							
lf. samples	59	41	16	16	26	27	2
stick samples	47	42	15	18	21	23	4

Changes in overall frequencies since 1978 of the principal pathogenicity characters on non-corresponding hosts are shown in Table 4. The frequencies of BMV 3 and BMR 6 and 6+Ab were maintained and there were decreases in the frequencies of BMV 4 and 5, confirmed by the decrease in the frequency of the combination, BMV 4+5. Indeed, in trials in 1984 at the Plant Breeding Institute, the matching cv. Egmont (BMR 4+5) had less mildew and was heavier yielding than in previous years. From the population structure of the pathogen and the continuation in popularity of cv. Triumph in 1985, it can be predicted that cv. Egmont and others with similar resistance will again perform well in 1985.

Table 4. Values for non-corresponding pathogenicity, 1978-84

Year	2	3	4	5	6	2+5	3+4	4+5	6+Ab
1978	72	22	9	22	22				
1979	60	23	12	28	21				
1980	71	26	17	27	25				
1981	74	22	26	25	14				
1982a	48	43	28	23	9				
b	59	29	28	39	10	37	7	15	6
1983b	63	49	35	30	21	29	11	14	22
1984a	64	42	22	17	24	15	6	6	22
b	48	42	16	21	22	18	8	6	24

a conventional survey samples; b plot samples from NIAB regional centres

Table 5 shows the pathogenicity of the airborne spore population in WIST samples obtained from eastern England in 1982-84 and tested on differential cultivars. These data are compared in the Table with similar data for non-corresponding pathogenicity obtained from the plot spore samples (see Table 4). The plot data, of course, exclude the values for corresponding pathogenicity and the numbers of plots sampled do not reflect cultivar frequency in agriculture. The WIST samples, on the other hand, directly reflect the popularity of susceptible cultivars, and the numbers of colonies of each pathogenicity character include infections generated from non-corresponding cultivars.

BMV 2 and 3+4 remained more or less constant over the three-year period, at similar levels in each survey. However, BMV 3, 6 and 6+Ab were all higher, and BMV 3 increased from 1982 to 1983, and BMV 6 and 6+Ab from 1983 to 1984, in the WIST surveys. This was because the WIST samples reflected the prevalent influence of the triazole fungicides, with which BMV 3 was

associated, and the high proportion of increasingly susceptible crops of cv. Triumph and related cultivars which selected for BMV 6+Ab, but also BMV 3. Concomitantly, BMV 4, 5, 2+5 and 4+5 all declined, to give lower values in the WIST than in the plot samples, emphasising the potential value of BMR 4 and 5 in eastern England, at least for 1985.

Table 5. Comparison of non-corresponding pathogenicity values obtained from plot samples with overall pathogenicity values from the WIST obtained in eastern England, 1983-84

Source	BMV character 2	3	4	5	6	6+Ab	2+5	3+4	4+5
Plot samples									
1982	59	29	28	39	10	6	37	7	15
1983	63	49	35	30	21	27	24	11	16
1984	48	42	16	21	22	24	18	8	6
WIST samples									
1982	57	42	30	-	35	37	45	6	21
1983	44	61	16	14	31	35	11	15	8
1984	48	60	15	7	54	53	11	7	1

Table 6 compares the WIST data from England and Scotland over the same period (1982-84). The trends in both countries are generally in the same direction, but the increase in BMV 6+Ab reveals the slower uptake of the corresponding host variety in Scotland compared with in England. Conversely, BMV 4 and 5 have declined more slowly in Scotland. It is possible that BMV 4 survives better in the generally cooler conditions in the north and that BMV 5 has been maintained partly because of its known association with insensitivity to ethirimol, which is more common in the north than in the south (see below).

Table 6. Pathogenicity of WIST isolates collected in England and Scotland, 1982-84

Source	1A	1B	2	3	4	5	6	6+Ab	2+5	3+4	4+5
England											
1982	-	-	57	42	30	-	35	37	45	6	21
1983	-	-	44	61	16	14	31	35	11	15	8
1984	36	33	48	60	15	7	54	53	11	7	1
Scotland											
1982	-	-	47	54	31	-	19	10	11	48	3
1983	-	-	49	57	27	33	14	13	26	8	3
1984	30	52	69	54	24	27	39	19	28	26	7

Pathogen population dynamics

Continuation of the weekly exposure of barley seedlings on the roof of the Botany School in Cambridge facilitated a comprehensive analysis of the dynamics of pathogenicity and insensitivity characters in the pathogen population. Figure 1 shows the flux in frequency of colony numbers, on a monthly basis, incubated from the exposed seedlings of untreated cv. Golden Promise. From these data, there appear to be six phases of change in the size of the pathogen population during the course of the year, as follows:

i. a population crash in August following harvest. The pathogen survives largely on volunteer plants.

ii. exponential increase during early autumn on emerging winter barley crops.

iii. late autumn decline as the average temperature falls

iv. winter survival during January and February

v. exponential increase in the spring

vi. maximum epidemic level in the early summer as each crop reaches its carrying capacity for the disease.

Each phase is important in relation to overall pathogen fitness and each may favour different genotypes. As a consequence, different pathogenicity and fungicide insensitivity characters may be favoured at different stages independently of the known selective influences. For example, Fig. 2 shows the frequency of different pathogenicity characters for late summer, 1983 (mean of 5 weeks), winter 1983-4 (mean of 17 weeks) and summer, 1984 (mean of 11 weeks). There was a tendency for the colony number on cv. Triumph to follow the overall increase on cv. Golden Promise whilst the numbers with BMV 2 and 4 decreased overall as a concomitant effect. However, it appears from Fig. 2 that BMV 4, and possibly BMV 5, were maintained to some extent by relatively better winter survival than was evident for BMV 2, 6 and 6+Ab.

These differences were reflected in a comparison of rates of change during the exponential phases in autumn, 1983 (early and late), and spring, 1984 (Fig. 3). These were measured as the slope of $\log_e$ of the colony numbers counted for each week during the exponential phase. BMV 6+Ab increased as fast as pathogenicity on cv. Golden Promise in autumn, 1983 and spring, 1984, but decreased more rapidly during late autumn, 1983, presumably in the pathogen populations on winter barley. Conversely, BMV 4 tended to show slower rates of increase, and also a slower rate of decline in the unfavourable conditions of late autumn, 1983.

The rates of increase in pathogenicity on cv. Golden Promise in early autumn, 1983 (0.815±0.139) and early autumn, 1984 (0.608±0.102) were both higher than in spring, 1984 (0.498±0.061). This difference may indicate that, in the early autumn, the pathogen population is being supplemented by the germination of cleistothecia, releasing ascospores that initiate new populations additional to those surviving asexually. If so, it may be possible to estimate the contribution of ascospores each autumn by the difference between the spring and autumn infection rates for each pathogenicity and fungicide insensitivity character.

In spring 1984, the rates of increase of fungicide insensitivity (0.464± 0.028 and 0.490±0.059 respectively for seedlings treated at 0.025 and 0.125 g a.i. triadimenol per kg seed) were similar to that obtained for untreated cv. Golden Promise. In autumn 1984, however, fungicide insensitivity increased at a slower rate, relative to that for untreated cv. Golden Promise. It is not yet known whether this is a common difference between spring and autumn, or whether there has been a reduction in fungicide insensitivity.

The overall changes from July, 1984, are given in Table 7, relative to the values obtained for cv. Golden Promise at each time.

Figure 1. Numbers of mildew colonies per set of 60 seedlings of cv. Golden Promise per week (————) following exposure on a roof in Cambridge in the period July, 1983 to December, 1984. From subsequent laboratory tests, the pathogenicity on BMR 6+Ab (Triumph: .....) and insensitivity to triadimenol (0.025 g a.i. per kg seed: --------) were determined as absolute proportions of the total colony numbers on cv. Golden Promise

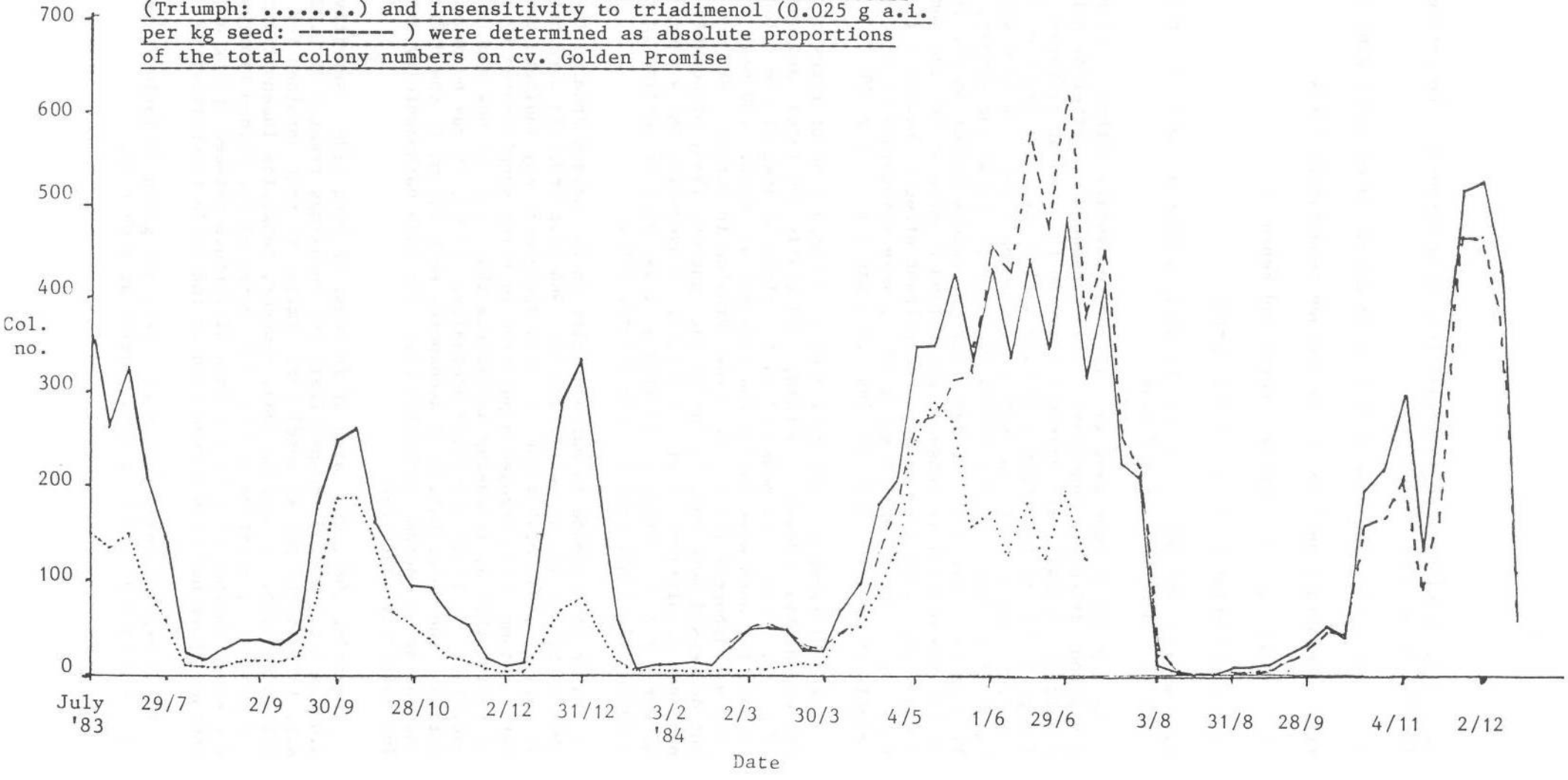

Figure 2. Mean numbers of mildew colonies per set of 60 seedlings of cv. Golden Promise per week (G.P.) following exposure on a roof in Cambridge in the periods late summer, 1983 (5 weeks: a.), winter, 1983-84 (17 weeks: b.) and summer, 1984 (11 weeks: c.). From subsequent laboratory tests, the pathogenicity on BMR 2, 3, 4, 5, 6 and 6+Ab were determined as absolute proportions of the total colony numbers on cv. Golden Promise

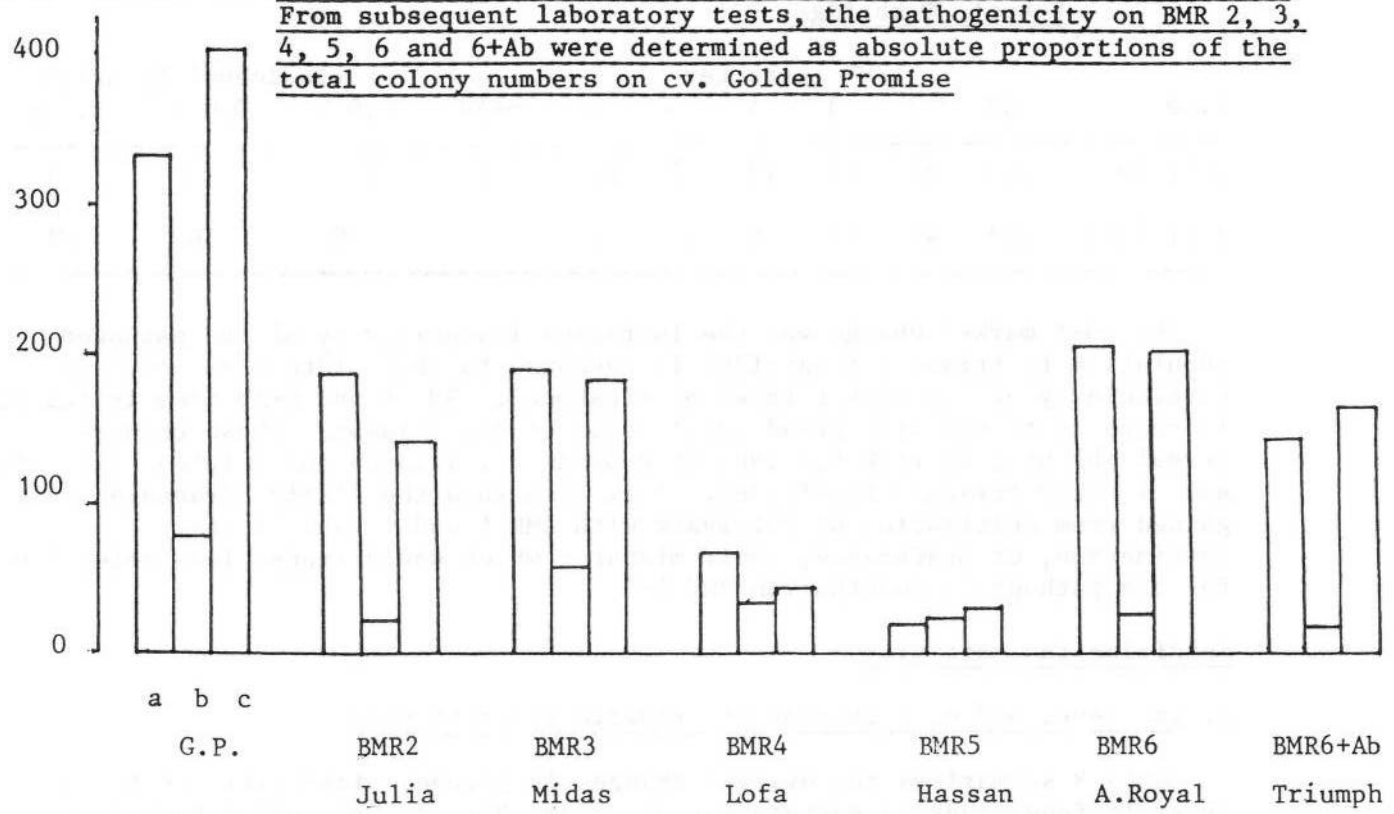

Figure 3. Slope of the change in colony numbers per week ($\log_e$) on cv. Golden Promise, BMR 4 and BMR 6+Ab during the exponential phase of increase in autumn, 1983 (a), decrease in late autumn, 1983 (b) and increase in spring, 1984 (c), determined from the source of data for Fig. 1

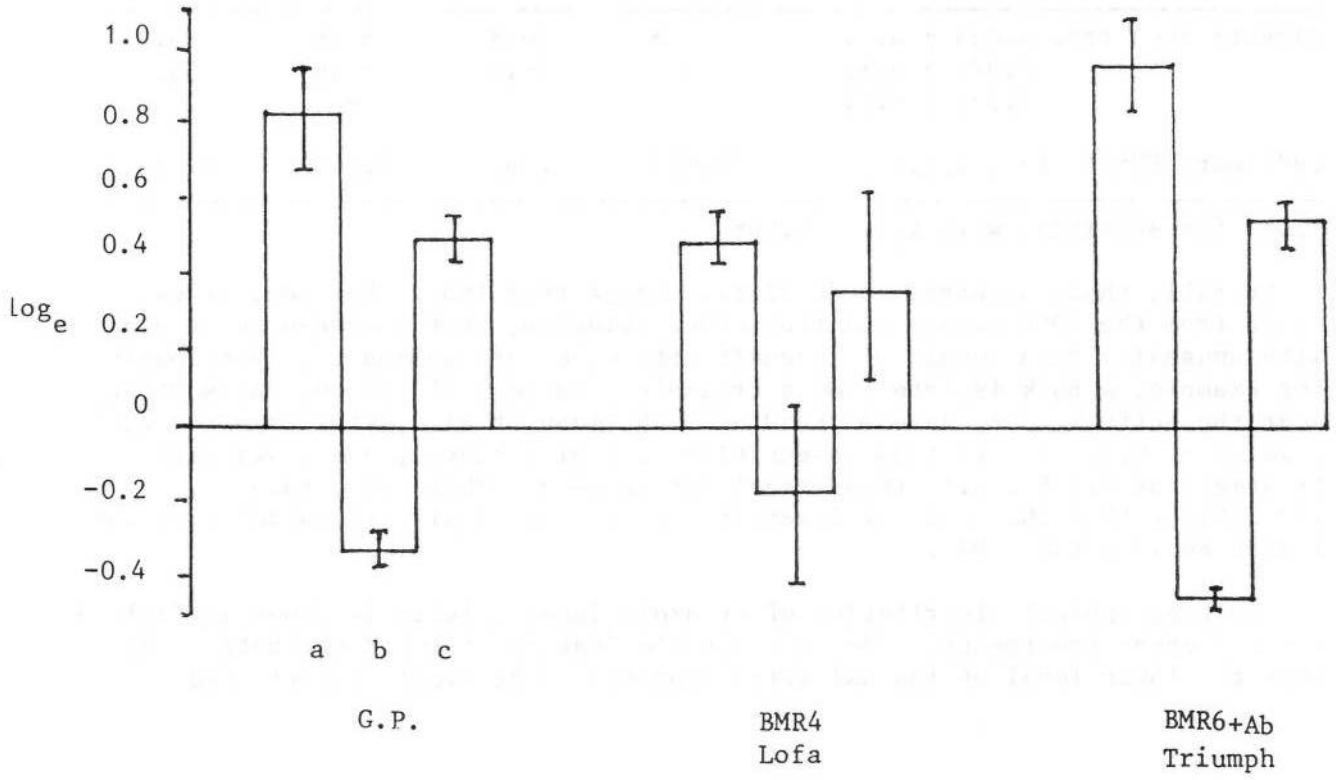

Table 7. Pathogenicity and triazole insensitivity values for July 1983 and July 1984, measured by indirect tests of mildew samples obtained from cv. Golden Promise seedlings exposed on the roof of the Botany School, Cambridge

Time	BMV character							triadimenol (g a.i.)		
	GP	2	3	4	5	6	6+Ab	0.025	0.075	0.125
July 1983	100	57	61	19	7	62	46	118	24	11
July 1984	100	48	62	9	12	70	50	138	56	21

The most marked change was the increased insensitivity of the pathogen population to triazole fungicides in response to their intensive use, and particularly at the higher rates of treatment. BMV 6 and 6+Ab also increased, in response to the widespread cultivation of cv. Triumph. These changes reveal the obvious risk for 1985 of growing cv. Triumph and related cultivars, and of using triazole fungicides. They also show the likely advantage to be gained from cultivation of cultivars with BMR 4 and 5, and of their combination, or preferably, their mixture, which would impose less selection for the pathogenic combination BMV 4+5.

Fungicide insensitivity

a. The level and distribution of triazole insensitivity

Table 8 summarises the overall changes in pathogen insensitivity to the triazole fungicides in eastern England from 1981 to 1984, using both direct and indirect tests.

Table 8. Insensitivity to triazole fungicides in eastern England measured directly (relative colony counts on treated exposed seedlings) or indirectly (ED50 samples from untreated exposed seedlings)

Method	1981	1982	1983	1984
Direct: seed trt. 0.025 g a.i.	22.6	50.8	82.6	85.0
0.075 g a.i.	-	26.8	53.6	53.8
0.125 g a.i.	-	-	-	24.0
Indirect: ED50* (in g a.i.)	0.028	0.060	0.080	0.133

*ED50 for sensitive wild type = 0.008

Overall, there appeared to be little change from 1983. However, it was clear from the ED50 values and from other evidence, that pathogen genotypes with unusually high levels of insensitivity were more common than previously. For example, a bulk isolate from a triazole-treated field of cv. Maris Otter near the Suffolk coast gave an ED50 of 0.66 (mean of six tests) compared with a value of 0.11 for previous insensitive control isolates, and a standard treatment of 0.375 g a.i. triadimenol per kg seed. There are, however, indications that the level of insensitivity in East Anglia in autumn 1984 was less than in autumn 1983.

The geographical distribution of triazole insensitivity is shown in Table 9 for different treatments. The most notable feature of the distribution was that the lower level of insensitivity appeared to be widely distributed

throughout the country, whereas the higher level was more evident in eastern England and less so in the north and south-west. This probably reflects the more intensive use of triazole fungicides in eastern England than elsewhere, during 1983 and 1984.

Table 9. Insensitivity to triazole fungicides in Scotland and England measured directly (relative colony counts on treated exposed seedlings) or indirectly (ED50 samples from untreated exposed seedlings

Area	No. of bulks	Test seedling dose (g a.i.) 0.025	0.075	0.125	ED50
N. Scotland	4	81	46	12	0.07
E. Scotland	4	110	58	16	0.08
Lothians	3	101	46	22	0.08
N. England	2	56	152	35	0.11
E. Midlands	6	117	159	80	0.28
SW. Midlands	5	68	51	24	0.13
Anglia	4	64	69	61	0.16
SE. England	3	99	57	44	0.12
SW. England	2	71	65	15	0.07

b. The distribution of insensitivity to other fungicides

Pathogen isolates varying in sensitivity to ethirimol can be found in England and Scotland, but the less sensitive isolates are more common in Scotland (Table 10). Single colony isolates with reduced sensitivity to tridemorph have not been separated, but there again appears to be a similar distribution of variation in populations of the pathogen, with less sensitivity in Scotland than in England. It is not yet known whether the apparent response to tridemorph is related to variation in response to fenpropimorph; data obtained with the latter fungicide are highly variable.

Not surprisingly, values for insensitivity to triadimenol obtained from the populations collected on triadimenol-treated seedlings were higher than those from the populations collected on untreated seedlings. In this respect there was little difference between the data from England and Scotland. For both ethirimol and tridemorph, particularly at the higher rates of treatment on the test seedlings, colony numbers, and therefore the level of insensitivity, were markedly higher for Scottish compared with English isolates.

It was also notable that the greater levels of insensitivity to ethirimol and to tridemorph in the Scottish isolates were as high in the population samples obtained from triadimenol-treated seedlings as in those obtained from untreated seedlings. It seems that the current level of insensitivity in the pathogen population to ethirimol and to tridemorph can be associated with insensitivity to triadimenol, in contrast with the observations from the previous year which indicated some negative association of insensitivity characters (Wolfe, Slater & Minchin, 1984).

Table 10. Relative colony counts for isolates obtained on untreated or triadimenol-treated seedlings of cv. Golden Promise in England and Scotland and tested on seedlings treated at two rates of triadimenol (0.025 and 0.125 g a.i.), two rates of ethirimol (1/8, 1/4 field rate) or two rates of tridemorph (1/20, 1/10 field rate)

		Test fungicide					
		Triadimenol		Ethirimol		Tridemorph	
Source	No.	0.025	0.125	1/8	1/4	1/20	1/10
England							
untrt.	(35)	81	11	15	8	76	19
triad.-trt.	(54)	77	26	17	7	56	15
Scotland							
untrt.	(14)	77	12	36	23	84	53
triad.-trt.	(40)	81	22	50	32	85	47

c. Triadimenol-insensitivity and specific pathogenicity

The isolates obtained from different parts of England and Scotland on untreated and triadimenol-treated seedlings of cv. Golden Promise were also tested on a range of differential cultivars (Table 11).

Table 11. Pathogenicity of isolates obtained in the WIST on untreated and triadimenol-treated seedlings of cv. Golden Promise

Area/trt.		1A	1B	2	3	4	5	6	6+Ab	2+5	3+4	4+5
E. Scotland	unt.	58	55	96	27	20	49	60	11	45	31	0
	trt.	21	33	52	33	13	41	18	21	20	11	0
Lothians	unt.	16	51	55	67	26	16	28	23	20	24	11
	trt.	30	37	61	64	46	16	33	32	10	25	11
N. England	unt.	21	30	40	42	30	15	32	26	26	13	2
	trt.	23	40	68	25	26	0	50	12	0	32	0
E. Mids.	unt.	65	68	70	73	7	6	86	80	5	9	2
	trt.	62	58	66	83	27	15	74	65	21	15	10
E. Anglia	unt.	40	32	54	64	10	5	62	50	10	9	1
	trt.	34	37	48	57	14	8	59	51	12	11	3

From Table 11, there were no instances of consistent differences in specific pathogenicity between population samples from untreated and treated seedlings. This may have been because of the general shift towards insensitivity in the pathogen population. It was evident, however, that BMV 3 was common in the areas where triadimenol-insensitivity was highest, and that BMV 5 was common in Scotland where the population was least sensitive to ethirimol.

REFERENCE

Wolfe, M.S., Slater, S.E. and Minchin, P.N. (1984). Mildew of Barley. United Kingdom Cereal Pathogen Virulence Survey 1983 Annual Report, 42-49.

MILDEW OF BARLEY IN NORTHERN IRELAND

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Pathogen virulences of barley mildew in Northern Ireland were reported separately in the UKCPVS Annual Report for the first time in 1983. In 1984 the techniques were altered slightly in an attempt to make comparison with results from Great Britain more meaningful. All pustules were counted under a binocular microscope and not the maximum visual count of 50, which was used previously. Any lesion showing hyphal growth was deemed to be a pustule.

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	Hassan
6	Wing
7	Tyra
8	Akka
3+4	Goldspear
4+5	Egmont
4+6	Dram
6+Ab	Triumph

Table 2 shows values for the mean pathogenicity of isolates taken from 22 crops. Only four cultivars were sampled - Golden Promise, Igri, Goldmarker and Triumph. Table 3 shows a comparison of non-corresponding pathogenicity values for Northern Ireland in the last two years compared with those obtained in England, in 1983 by a modified mobile nursery technique of NIAB regional centres (Wolfe et al, 1984: Table 3) and in 1984 by conventional survey methods (Wolfe et al, 1985: Table 3).

The modified techniques appear to have brought the Northern Ireland figures for 1984 into broad agreement both with the previous year's scaled-down figures and with those from England. As in 1983 the combined virulence 4+5 in Northern Ireland is considerably higher than in England; that of 3+4 is also higher, but both Northern Irish and English figures are generally lower than in the previous year. Taking into account the scaling factor, corresponding pathogenicity for 6+Ab increas from c.46 in 1983 to 56 in 1984; non-corresponding pathogenicity was similar at 24.

Table 2 Mean pathogenicity of bulk isolates in 1984 on test range of cultivars

			BMV characters										
BMR GROUP	ISOLATE SOURCE	Number	2	3	4	5	6	7	8	3+4	4+5	4+6	6+Ab
0	Golden Promise	6	60	74	36	46	10	0	2	27	41	5	34
1	Igri	7	53	33	48	37	22	0	7	25	32	7	20
3+4	Goldmarker	5	39	62	43	32	17	0	6	34	31	10	18
6+Ab	Triumph	4	33	39	42	44	85	1	11	39	54	58	56

Table 3 Comparison of non-corresponding pathogenicity values in Northern Ireland and England, 1983/84

	BMV Character							
	2	3	4	5	6	3+4	4+5	6+Ab
N Ireland (1983)*	59	53	59	37	16	45	32	22
N Ireland (1984)	48	45	42	40	17	29	38	24
England (1983)	65	48	35	27	17	11	14	22
England (1984)	64	42	22	17	24	6	6	22

* N Ireland 1983 data scaled to levels of BMV 2 and 3 similar to those in England; 1984 data unaltered.

The increase in corresponding pathogenicity for 6+Ab did not seem to be reflected on farms (Table 4). Although some crops of cv. Triumph were quite

Table 4 Percentage of leaf area of cultivar affected by mildew in surveys of spring barley in 1983 and 1984

Cultivar	Percentage mildew 1983	1984
Golden Promise	19.4	34.4
Goldmarker	10.6	16.6
Patty	0.0	8.0
Triumph	1.7	2.3
Atem	-	0.0

heavily infected, on average there was little increase in percentage mildew from the low level of the previous year, in spite of a general increase in mildew as evidenced by cv. Golden Promise. Atem was the only cultivar to show no field-infection by mildew in 1984.

REFERENCES

Wolfe M S Slater S E and Minchin P N (1984). Mildew of barley. United Kingdom Cereal Pathogen Virulence Survey Annual Report; 42-49.

Wolfe M S Slater S E and Minchin P N (1985). Mildew of barley. United Kingdom Cereal Pathogen Virulence Survey Annual Report; (this report).

YELLOW RUST OF BARLEY

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Seven samples were received during 1984. All possessed BYV 1 and BYV 2, and six were virulent on Triumph (BYV 3).

In adult plant tests using winter cultivars, no cultivar x isolate interactions were apparent, although isolate 82/12 produced increased levels of infection on most cultivars as in 1983. With spring cultivars, interactions of certain isolates with Triumph and related cultivars were clearly detected at the seedling stage, but were less evident in adult plants.

INTRODUCTION

The specific resistances (BYR factors) identified in barley cultivars to date, the test 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 P. striiformis

BYR Factor	Test cultivars	Type*	Year virulence detected
BYR 1	Astrix	Overall	1960
BYR 2	Bigo, Varunda, Mazurka	Overall) Seedling)	1972-75
BYR 3	Triumph	Seedling?	1983

* sensu Zadoks; overall resistance is effective at all growth stages, seedling resistance is ineffective at adult plant growth stages.

METHODS

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

Seedling tests with 1984 isolates

Only seven samples were received in 1984. This reflected the generally very poor conditions for yellow rust development, with a hot, dry period early in the season and little subsequent rain. Samples had been collected in a non-random way from one winter cultivar and six spring cultivars. Isolates were made from all samples, and virulence tests carried out.

RESULTS

Virulence frequencies for 1972-1984 are shown in Table 2. BYV 1 and BYV 2 were detected in all isolates in 1984, and BYV 3 in six out of the seven.

Sample size in 1984 was very small, and figures should be interpreted with extreme caution.

Table 2. Virulence factor frequency (%)

BYV Factor	Common name	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984
BYV 1	Astrix virulence	93	99	100	97	100	100	98	-	100	100	100	100	(100)
BYV 2	Bigo virulence	0	0	0	3	0	18	32	-	54	81	96	87	(100)
BYV 3 ≠	Triumph virulence	-	-	-	-	-	-	-	-	-	-	-	17	(86)
Number of isolates tested		55	82	109	69	17	27	44	1	56	52	25	30	7

( ) = limited data

≠ Not included in tests before 1983

Adult Plant tests in 1984

a) Winter barley cultivars

Tests carried out in 1983 did not indicate any obvious cultivar x isolate interactions, although isolate 82/12 gave generally increased infection on most cultivars. The Polythene tunnel tests in 1984 were designed to determine whether this effect was repeatable.

Eighteen cultivars were tested as adult plants and seedlings. Details of the isolates used are given in Table 3. Seedling tests were carried out in controlled environment chambers (16 hour day at 18°C, 8 hour night at 11°C).

For adult plant tests, four replicate tussocks were sown on 24-25 November in Polythene tunnels, inoculated on 23 March and 19 April and assessed for percentage leaf area infected on 3 May (GS 47), 11 May (GS 54), 22 May (GS 60) and 4 June (GS 69).

Table 3. Isolates of P. striiformis used in adult plant tests of winter barley cultivars

Code	Cultivar	Region*	Site	BYV Factors
Control isolate				
75/101	Varunda	YL	Boroughbridge	1,2
Test isolates				
82/12	Marko	S	Edinburgh	1
82/22	Medallion	S	Midlothian	1,2

*YL = Yorks and Lancs, S = Scotland

Table 4. Yellow Rust of Barley (winter cultivars). Results of adult plant tests 1984.

Values are mean percent leaf area infection (average of four assessment dates).

Isolate	75/101	82/22	82/12
BYV Factors	1,2	1,2	1
Cultivar			
Opera	2	0	4
Nevada	3	1	4
Libra	2	4	3
Igri	8	6	12
Maris Otter	12	21	15
Halcyon	9	16	23
Pirate	14	16	23
Impact	19*	14	23
Monix	19	20	30
Natalie	18	24	28
Metro	24	17	31
Panda	23*	29*	29*
Athene	27	27	29
Gerbel	23	28	34
Tipper	31	26	37
Sonja	33	37	36
Fulmar	37	28	43
Astrix	28	34	48
Mean	18	19	25

* = resistant reaction type($\leq$2.0) in seedling tests.

All other cultivar isolate combinations gave susceptible reaction types ($>$2.0).

RESULTS

Mean disease levels are given in Table 4. The cultivar Panda was resistant to all isolates as a seedling, but was very susceptible as an adult plant. All other cultivar/isolate combinations gave susceptible reactions in seedling tests with the exception of Impact with 75/101. As in 1983, there was no evidence of any cultivar x isolate interaction at the adult plant stage. General infection levels were much higher than in 1983, but it was still clear that isolate 82/12 produced higher infection than the other two isolates tested. Mean infection levels over all cultivars were 4%, 5% and 9% in 1983 for 75/101, 82/22 and 82/12 respectively, whilst in 1984 the corresponding figures were 18%, 19% and 25%.

It appears that 82/12 does consistently produce higher levels of infection on winter barley cultivars than other isolates tested in Polythene tunnels, and this may indicate a general adaptation to winter cultivars. The frequency of isolates such as 82/12 is unknown. Eight isolates from winter cultivars were used in tunnel tests in 1983; of these only 82/12 gave increased infection levels over a wide range of cultivars.

b) Spring barley cultivars

Detection of seedling virulence for Triumph in 1983 prompted a re-introduction of adult plant Polythene tunnel tests with spring barley cultivars. Twenty-four spring barley cultivars were tested as seedlings and adult plants with the isolates detailed in Table 5.

Table 5. Isolates of P. striiformis used in adult plant tests of spring barley cultivars.

Code	Cultivar	Region*	Site	BYV Factors
Control isolate				
75/101	Varunda	YL	Boroughbridge	1,2
1983 isolates				
83/38	Triumph	WM	Farndon	1,2,3
83/39	Tasman	WM	Farndon	1,(2),(3)
Other isolates				
82/12	Marko	S	Edinburgh	1

*YL = Yorks and Lancs, WM = West Midlands, S = Scotland.

( ) = partially virulent on corresponding resistance.

Seedling tests were carried out in controlled environment chambers. For adult plant tests, three replicate tussocks were sown on 7 March in Polythene tunnels, inoculated on 2 and 17 May, and assessed on 31 May (GS 45), 11 June (GS 64) and 20 June (GS 70).

RESULTS

Mean disease levels are given in Table 6.

Three cultivars known to possess BYR 1 (Apex, Atem and Zephyr) were susceptible to all four isolates.

Bigo, Varunda and Mazurka (BYR 2 cultivars) were resistant to 82/12 at the seedling stage. The results confirmed that the resistance of Mazurka is not effective at the adult plant stage.

Triumph, together with Tasman, Natasha, Acclaim and Carnival (cultivars with Triumph, or its equivalent Trumpf, in their parentage), were resistant to 82/12 and 75/101 as seedlings, but susceptible to 83/38 (BYV 1,2,3) and have therefore been classified as possessing the resistance BYR 3. Seedling reactions to isolate 83/39 were inconsistent within this group of cultivars and it appears that the virulence of 83/39 for BYR 3 was only partial. As in previous years, the resistance detected in seedlings of Triumph and related cultivars was not effective at the adult plant stage. However, there was a tendency for cultivars in this group to show higher levels of infection with isolate 83/38 (possessing BYV 3) than with isolates 82/12 and 75/101 (lacking BYV 3). It is not clear from the data whether this was due to increased virulence of 83/38 specifically for BYR 3 cultivars or to a more general increase in aggressiveness of this isolate for a range of cultivars irrespective of their specific resistances. It is noticeable, for example, that 83/38 produced increased infection levels on a number of the more resistant cultivars, including Apex, Atem, Patty and Vista. It is also known that isolates avirulent on seedlings of Triumph are capable of producing high levels of infection on adult plants of the cultivar. Virulence of 83/38 for the seedling resistance of Triumph may therefore be unrelated to its aggressiveness on adult plants.

Isolate 82/12 was included in spring cultivar tests to investigate whether the increased infection levels produced by this isolate on winter barleys would be observed on spring cultivars. The data in Table 6 show that this did not occur; 82/12 produced very similar infection levels to the control isolate 75/101 on all cultivars with the exception of the BYR 2 cultivars.

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Table 6. Yellow Rust of Barley (spring cultivars). Results of adult plant tests 1984

Values are mean percent leaf area infection (average of three assessment dates).

Isolate		82/12	75/101	83/39	83/38
BYV Factors		1	1,2	1,(2),(3)	1,2,3,
Cultivar	BYR Factor				
Apex	1	12	7	11	17
Atem	1	12	7	15	20
Zephyr	1	25	17	28	26
Bigo	2	0*	16	2	5
Varunda	2	8*	23	14	19
Mazurka	2 (seedling)	16*	32	19*	23
Triumph	3	8*	7*	9	17
Tasman	3	6*	2*	1	12
Natasha	3	10*	16*	14	28
Acclaim	3	3*	4*	5*	10
Carnival	3	6*	3*	9*	9
Doublet	?	5*	4	5	11
Patty		2	3	3	7
Vista		8	10	15	22
Goldmarker		19	15	14	18
Themis		17	30	13	22
Kym		23	16	18	26
Golf		18	22	19	26
Koru		24	22	15	25
Efron		20	22	24	22
Roland		26	23	16	26
Delta		25	24	26	30
Keg		30	38	33	36
Klaxon		31	37	38	32

( ) = partial virulence

* = Resistant reaction type($\ll 2.0$) in seedling tests.

All other cultivar isolate combinations gave susceptible reaction types.

BROWN RUST OF BARLEY

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One previously unidentified virulence combination was detected in the seedling tests of 24 isolates of Puccinia hordei Otth. This isolate, octal race 633, is unlikely to be of any agricultural significance as it is less widely virulent than previously identified races. The number of isolates carrying virulence to cv. Triumph continues to increase (87.5% of viable samples). Winter cultivars inoculated with a cv. Triumph-virulent isolate, in a field isolation nursery, were all susceptible, although quantitative differences in levels of infection were apparent. Comparisons between nurseries inoculated with the widely virulent race 673T and the simple race 11 allowed identification of specific resistances within the spring cultivars.

GLASSHOUSE SEEDLING TEST WITH 1984 ISOLATES

Eighteen of the 27 samples received during 1984 were from the east of England. Isolates were made from 24 samples, the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cv. Midas. Seedling tests were carried out on each isolate to determine the presence of virulence factors compatible with the specific resistances identified in the standard set of 9 differential cultivars (Table 1). Cvs Triumph and Carnival were included in all tests.

Table 1. Standard differential cultivars

C.I. Number	Cultivar	Gene symbol
6489	Sudan	Pa
935	Peruvian	Pa_2
-	Ribari	Pa_3
1145	Gold	Pa_4
1024	Quinn	Pa_5
1257	Bolivia	Pa_6
6193	Cebada Capa	Pa_7
6481	Egypt 4	Pa_8
1243		Pa_9

Results

The numbers of each octal race identified are given in Table 2.

Table 2. Races identified from 1984 isolates

Number of isolates	Octal designation
12	673 TC*
9	653 TC
2	673
1	633

*TC - also virulent on cvs Triumph and Carnival

Isolate BRS-84-2 from an unknown cultivar gave a previously unidentified virulence combination. The isolate, octal race 633, which lacks virulence to the differential cv. Bolivia (gene Pa_2, Pa_6) is less widely virulent than previously identified common races. Two samples from trial sites gave a mixed reaction on cv. Ribari (Pa_3). Further tests of compatible pustules are in progress to confirm this virulence. This is the first time since 1977 that compatibility to this differential cultivar has been identified.

The spectra of virulence of a range of important isolates and their corresponding octal designations are given in Table 3.

Table 3. Virulence spectra and octal designations of important isolates of P.hordei

Resistance gene:										
Fixed linear order:	Pa_9	Pa_8	Pa_7	Pa_6	Pa_5	Pa_4	Pa_3	Pa_2	Pa	Octal no. (race)
	1	1	0	1	1	1	1	1	1	677
	1	1	0	1	1	1	0	1	1	673
	0	1	0	1	0	1	1	1	1	257
	1	1	0	1	0	1	0	1	1	653
	1	1	0	0	1	1	0	1	1	633

1 = Susceptible; 0 = Resistant

The majority of the isolates tested were virulent on cv. Triumph. Virulence to this cultivar has increased dramatically since it was first detected in 1981 (Table 1).

Table 4. Frequency of virulence to cv Triumph

UK CPV Survey Year	% of isolates virulent on cv. Triumph	Total no. of viable samples
1981	3.8	52
1982	31.3	22
1983	66.6	21
1984	87.5	24

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Winter and spring cultivars were sown in each of two standard isolation nurseries. The nurseries were inoculated with one of two isolates of *P.hordei* in the late spring after establishment of the spring-sown cultivars. The isolates used were:

Octal race 673 with virulence to cv. Triumph
Octal race 11

Results

Octal race 11 failed to infect the winter cultivars, a reflection of the resistance of these cultivars to this simple race. High levels of infection developed on the susceptible spring cultivars inoculated with this isolate. The widely virulent race 673T infected both winter and spring cultivars. Results are summarised in Table 5a - winter cultivars, and Table 5b - spring cultivars.

All winter cultivars tested were susceptible to race 673T, although cvs Medallion and Opera gave a relatively low level of infection of a mixed reaction type. The spring cvs Acclaim, Doublet, Triumph, Natasha, Armelle, Delta and Klaxon all showed high levels of infection within this nursery, but they were only slightly infected by octal race 11.

Both isolates failed to overcome the specific resistance of cv. Simon (Pa_3). Cv. Roland was also resistant to both isolates, which suggests that it may carry gene Pa_3.

Table 5a. Barley Brown Rust Isolation Nurseries - 1984

Winter cultivar	Octal race 673 T		Octal race 11
	%	R.T.	
Sonja	43	S	0
Natalie	43	S	0
Nevada	41	S	0
Pepite	40	S	0
Vixen	38	S	0
Metro	38	S	0
Halcyon	38	S	0
Gerbel	36	S	0
Fulmar	35	S	0
Libra	35	S	0
Igri	34	S	0
Impact	34	S	0
Athene	33	S	0
Maris Otter	32	S	0
Pipkin	32	S	0
Pirate	30	S	0
Panda	27	S	0
Fenella	24	S	0
Tipper	22	S	0
Opera	19	MS	0
Monix	18	S	0
Medallion	15	MS	0

% = $\bar{x}$ of 4 replicates at 2 assessment dates
S = Susceptible; MS = Mixed susceptible

Table 5b. Barley Brown Rust Isolation Nurseries - 1984

Spring cultivar	Octal race 673 T %	Octal race 673 T R.T.	Octal race 11 %	Octal race 11 R.T.
Midas	42	S	45	S
Golden Promise	39	S	42	S
Atem	27	S	34	S
Koru	22	S	23	S
Efron	23	S	28	S
Themis	23	S	23	S
Golf	18	S	31	S
Acclaim	32	S	1	S
Doublet	33	S	3	MS
Triumph	27	S	2	S
Natasha	30	S	3	MS
Armelle	27	S	8	R
Delta	24	S	10	R
Klaxon	23	S	14	R
Vada	11	MR	20	MS
Kym	14	MR	25	S
Patty	9	MR	13	MS
Apex	14	MR	17	MS
Vista	15	MS	15	R
Tasman	11	MR	1	R
Simon	0		0	
Roland	0		Tr	R

% = $\bar{x}$ of 4 replicates at 2 assessment dates
S = Susceptible; R = Resistant; MS = Mixed susceptible

RHYNCHOSPORIUM OF BARLEY

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No new pathogen virulence factors were identified from the 16 isolates of Rhynchosporium secalis tested on seedlings in the 1984 survey. Cvs Gerbel and Tipper were relatively resistant to all isolates although three gave higher levels of infection on cv. Tipper. Isolates carrying BRV-1 were, with the exception of one, avirulent on cv. Pirate (BRR-7). A culture from a leaf sample of Italian ryegrass successfully infected barley. Low levels of disease in field isolation nurseries rendered results difficult to interpret. Cv. Fenella was one of the most highly infected winter barleys when inoculated with octal race 0. This confirms results of the previous year. Cv. Pipkin resembles the spring cv. La Mesita (BRR-5) in being resistant at the seedling stage to isolate Rs-83-25, which does not carry BRV-5, but being susceptible on the upper leaves in the field. The resistance of cv. Corgi, which carries the same resistance gene (Rh^4) remained effective against this isolate. The virulence of isolate Rs-83-14 (BRV-5) in seedling tests to cultivars carrying the Rh^4 resistance gene was confirmed by adult plant tests in controlled environment conditions.

SEEDLING TESTS WITH 1984 ISOLATES

The dry spring and summer experienced in Wales and south-west England was reflected in a lower than usual number (33) of Rhynchosporium-infected leaf samples received. The majority were from the east of England (11) and Scotland (11). The remainder from Wales (9) and south-west of England (2) included five samples on which no Rhynchosporium infection could be identified. An isolate from an infected leaf sample of Italian ryegrass (Lolium italicum) from Angus, Scotland, gave typical Rhynchosporium secalis infection symptoms on barley. The standard set of differential cultivars was extended to include cv. Pirate which has been assigned the resistance factor BRR-7. Test cultivars and their resistance factors are given in Table 1.

Table 1. Differential test-cultivars for Rhynchosporium secalis

Resistance 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

When classified by their reactions on the standard set of differential cultivars, the 15 isolates successfully cultured from the barley samples gave a range of different known virulence combinations. Each identified virulence combination has been designated an octal virulence number (Jones & Clifford, 1984) based on the octal/binary system proposed by Gilmour (1973) (Table 2).

Table 2. Virulence factor combinations (races) identified from the 1984 survey

No. of isolates	Differential cultivars in fixed linear order: Pirate BRR-7	Osiris BRR-6	La Mesita BRR-5	Igri BRR-4	Athene BRR-3	Astrix BRR-2	Armelle BRR-1	Octal virulence designation
6	1	0	0	1	1	0	0	114
4	0	0	0	1	1	1	1	17
2	1	0	0	0	0	0	0	100
1	0	0	0	1	1	0	0	14
1	1	0	0	0	1	0	0	104
1	1	0	0	1	1	1	1	117

Cv. Pirate (BRR-7) was resistant to all isolates carrying BRV-1, with the exception of isolate Rs-84-22 which gave an infection level of 15% leaf area infected. Three isolates not carrying this virulence factor were virulent on cv. Pirate and two isolates gave low levels of infection. These observations suggest that there may be a negative relationship between the two virulences but no conclusions can be drawn from such limited data. The situation will be monitored further in future surveys. As in 1983, isolates were identified which differentiated cv. Astrix from cvs Gerbel and Tipper. Cvs Gerbel and Tipper were comparatively resistant to all isolates although three cultures, in particular Rs-84-22, gave higher levels of infection on cv. Tipper.

Virulence to cvs La Mesita (BRR-5) and Pipkin was not detected.

The Rhynchosporium-infected leaf sample of Italian ryegrass, Rs-84-7, was identified as octal race 17 based on its reactions with the standard differential cultivars.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Three nurseries comprising both winter and spring cultivars were each inoculated with a different R.secalis isolate. The isolates used are given in Table 3.

Table 3. Isolates used in field tests in 1984

UK CPV Survey code	Virulence characteristics	Octal designation
Rs-83-14	BRV-5	20
Rs-83-25	BRV-0	0
Rs-83-25	BRV-1,2,3,4	17

Results

The drought conditions of 1984 were not conducive to the development of scald within the nurseries and infection developed very late. Interpretation of the results, particularly assessment of the winter cultivars, should be made with caution. The results are summarised in Table 4a (winter cultivars) and Table 4b (spring cultivars). Disease levels on the winter cultivars inoculated with isolate R-83-23 were negligible and no scores were taken.

The tests failed to confirm the seedling virulence of isolate Rs-83-14 (BRV-5) on cv. Pipkin at the adult plant stage. This, however, is probably a reflection of the generally low levels of infection on the winter cultivars - the susceptible winter cv. Maris Otter having only 5% leaf area infected. The spring cv. Corgi which carries the same resistance gene (RH^4) as cv. Pipkin was the most susceptible of the spring cultivars inoculated with this isolate. Cv. Osiris (BRR-6) which was seedling resistant (Jones & Clifford, 1984) to isolate Rs-83-14 was also resistant on its upper leaves.

The higher level of infection observed on the susceptible cultivars infected with isolate Rs-83-25 (BRV-0) was probably attributable to the location of this nursery at a site where moisture levels were higher. Cv. Pipkin was heavily infected on the flag leaf although it is resistant to this isolate at the seedling stage. This pattern of response has previously been observed with the spring cv. La Mesita (BRR-5) (Clifford & Jones, 1982). Cvs Corgi and Osiris (BRR-6) were both resistant. Isolate Rs-83-25 (BRV-0) was virulent on cv. Fenella and this confirms the previous year's results when isolate Rs-81-77, also BRV-0, was virulent on this cultivar.

Cv. Armelle (BRR-1) was resistant to isolate Rs-83-25 but more susceptible to Rs-83-23 (octal race 17) as was cv. Koru, confirming that they carry the same resistance.

ADULT PLANT TESTS IN CONTROLLED CLIMATE

Because of the low levels of disease within the isolation nurseries in 1984, three isolates were inoculated onto adult plants grown in a spore-proofed glasshouse. The isolates used are given in Table 5.

Table 5. Isolates used in controlled climate tests, 1984

UK CPV Survey code	Virulence characteristics	Octal designation
Rs-84-11	BRV-0	0
Rs-83-14	BRV-5	20
Rs-83-23	BRV-1,2,3,4	17

Plants were grown to approximately growth stage 59 (Zadoks) and inoculated by spraying on a suspension of spores. Plants were then incubated at a temperature of 15°C in a dew chamber for 48 h and then transferred to a controlled climate room with a photoperiod of 16 h at a light intensity of 7.5 - 10 K lux and a constant temperature of 15°C.

Results

Assessments of percentage leaf area infected were made on the flag leaf, 14 days and 18 days after inoculation. Results are summarised in Table 6.

Table 6. Results of adult plant tests in a controlled environment to selected isolates of Rhynchosporium secalis

Test cultivar	Rs-84-11 (BRV-0)		Rs-83-14 (BRV-5)		Rs-83-23 (BRV-1,2,3,4)	
	14 days	18 days	14 days	18 days	14 days	18 days
Le Mesita	0	13.0	38.0	53.0	7.0	25.0
Osiris	0	0	0	0	0	0
15533 Co	0	0	65.0	85.0	0	3.0
Sergeant	3.0	9.0	60.0	70.0	1.0	5.0
Corgi	0	0	55.0	70.0	0	10.0
Pipkin	0	0	28.0	30.0	0	0
Sonja	0	13.0	33.0	55.0	35.0	40.0
Igri	0	0	9.0	12.0	9.0	23.0
Athene	8.0	25.0	30.0	43.0	65.0	70.0
Armelle	0	0	0	0	5.0	15.0
Gerbel	0	0	0	0	50.0	60.0
Maris Mink	18.0	20.0	60.0	65.0	23.0	23.0
Astrix	0	0	0	0	65.0	70.0
Hoppel	2.0	20.0	20.0	25.0	0	3

Each value = % infection, mean of 2 replicates

Cvs La Mesita, 15533 Co, Sergeant, Corgi and Pipkin were all resistant to isolates Rs-84-11, and Rs-83-23 when scored after fourteen days, but highly susceptible to isolate Rs-83-14 (BRV-5). This confirms seedling test results. The mature tissue susceptibility of some Rh^4-genotypes was again observed particularly with cvs La Mesita and Sargent and to a lesser extent with cv. Corgi infected with Rs-83-23. Although susceptible to all three isolates cvs Sonja and Athene also showed increasing susceptibility with time. Cv. Hoppel showed a specific interaction with isolate Rs-84-11 with regard to this effect. Such complex interactions between host genotype, pathogen isolate and environment confirm the need for caution in interpreting results of any specific test using glasshouse, controlled climate or field conditions.

The specific resistances of cvs Gerbel and Astrix were overcome by isolate Rs-83-23. Only low levels of infection were observed on cvs Armelle and Igri although both are highly susceptible to this isolate at the seedling stage. This confirms previous field assessments that these cultivars have additional adult plant resistance. Cv Osiris (BRR-6) remained resistant to all isolates.

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Table 4a. Percent infection in Rhynchosporium isolation nurseries - 1984

Winter cultivars	Isolate Rs-83-14 (BRV-5)	Isolate Rs-83-25 (BRV-0)
Pipkin	2.0	29.0
Maris Otter	5.0	21.0
Fenella	1.0	16.0
Panda	2.0	16.0
Sonja	1.0	14.0
Libra	4.0	12.0
Fulmar	3.0	11.0
Medallion	4.0	11.0
Tipper	6.0	11.0
Gerbel	2.0	9.0
Impact	2.0	8.0
Monix	2.0	8.0
Pepite	2.0	7.0
Metro	0	6.0
Hoppel	0.5	5.0
Athene	0	4.0
Igri	2.0	4.0
Pirate	0.3	4.0
Astrix	1.0	4.0
Halcyon	0.3	4.0
Nevada	6.0	4.0
Vixen	4.0	4.0
Opera	1.0	3.0
Natalie	0.3	2.0

$\bar{x}$ of 4 replicates, 1 scoring date

Table 4b. Percent infection in Rhynchosporium isolation nurseries - 1984

Spring cultivars	Isolate Rs-83-14 (BRV-5)	Isolate Rs-83-25 (BRV-0)	Isolate Rs-83-23 (BRV-1,2,3,4)
La Mesita	5.0	31.0	8.0
Efron	6.0	22.0	10.0
Apex	7.0	21.0	8.0
Acclaim	5.0	21.0	6.0
Themis	6.0	20.0	8.0
Kym	4.0	17.0	9.0
Natasha	7.0	17.0	9.0
Roland	6.0	16.0	6.0
Doublet	8.0	16.0	10.0
Delta	7.0	16.0	9.0
Patty	4.0	16.0	7.0
Atem	5.0	13.0	7.0
Golden Promise	7.0	11.0	7.0
Vista	7.0	8.0	8.0
Klaxon	5.0	7.0	8.0
Golf	7.0	7.0	6.0
Midas	7.0	7.0	7.0
Proctor	5.0	7.0	4.0
Tasman	6.0	3.0	10.0
Triumph	5.0	3.0	7.0
Corgi	10.0	2.0	4.0
Osiris	0.8	1.0	1.0
Armelle	0	0.5	6.0
Koru	0.5	0.5	6.0

$\bar{x}$ of 4 replicates, 2 scoring dates

NET BLOTCH OF BARLEY

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Isolates carrying between 1 and 7 specific virulences in various combinations were identified from the 9 isolates of Pyrenophora teres Drechs. tested on seedlings. Within the spring differential cultivars no virulence compatible with the specific resistances of cvs CI 5401, CI 9820, CI 4795, CI 4502 and CI 9214 was found. The winter cv. Code 65 was also resistant to all isolates. Cultivars carrying the Rhynchosporium resistance gene Rh^4 were susceptible to an isolate of P.teres f. maculata (spotting type). Very low levels of net blotch in the two isolation nurseries rendered results difficult to interpret particularly within the winter cultivars. An isolate of P.teres f. maculata, BNS-83-31, infected the cultivars with its typical spotting type lesions. The winter cultivars inoculated with this isolate showed a reverse order of resistance i.e. cultivars most susceptible to this isolate were the most resistant to the 'netting' isolates and vice versa but this relationship was not apparent in the spring cultivars. Cv. Triumph and its related cvs Doublet, Tasman and Acclaim were again the most susceptible of the spring cultivars to all of the isolates.

GLASSHOUSE SEEDLING TESTS WITH 1984 ISOLATES

Of the 18 samples of net blotch received 16 were from winter barley cultivars and 2 from spring cultivars. This low number of samples is a reflection of the relatively low incidence of disease in field crops during the late spring and summer of 1984. The majority of samples were from the east of England (8) and Scotland (6), only two samples being received from the normally more heavily infected crops of south-west England and Wales.

The isolates of Pyrenophora teres Drechs. were inoculated onto seedlings of the 13 standard differential cultivars plus 17 additional winter cultivars, using procedures described previously (Clifford & Jones, 1981).

Results

Nine isolates were successfully tested, 6 of these originating from the cv. Igri. The frequencies of individual virulences corresponding to resistance factors in the 13 differential cultivars together with virulence frequencies over the period 1981-1983 are given in Table 1.

Table 1. Frequencies of virulences corresponding to each differential cultivar (UK CPV Surveys 1981-1984)

Code number	Cultivar	Virulence frequency (%) 1981	1982	1983	1984	Mean
1	C.I. 5401	0	8	0	0	2
2	C.I. 6311	0	20	0	22	11
3	C.I. 9820	0	6	0	0	2
4	C.I. 739	0	39	24	33	24
5	C.I. 1243	0	27	0	44	18
6	C.I. 4795	0	22	0	0	6
7	C.I. 4502	0	9	0	0	2
8	C.I. 4979	0	31	0	44	19
9	Proctor	-	-	52	55	52
10	Code 65 (W)	0	16	19	0	9
11	C.I. 9518 (W)	66	88	90	100	86
12	Tenn. 61-119 (W)	71	55	19	44	47
13	C.I. 9214	-	11	9	0	7
Number of isolates tested		24	83	21	9	

(W) = Winter cv.

The very low number of samples tested renders it difficult to compare the frequencies of virulence in 1984 with previous years. The spring cultivars CI 5401, CI 9820, CI 4795, CI 4502 and CI 9214 confirmed their value for inclusion in breeding programmes by again expressing high levels of resistance. Virulence to CI 6311, CI 1243 and CI 4979, although not detected in 1983, was present in the pathogen population at levels similar to 1982. Of the three winter lines, CI 9518 was susceptible to all isolates, virulence to Tenn 61-119 increased to levels similar to those seen prior to 1983, and Code 65 was resistant to all isolates tested.

The virulences identified occurred in various combinations in the different isolates (Table 2). The virulence combinations, based on the differential code numbers (Table 1), gave a range from the single virulence factor 11 to the more complex and widely virulent 2, 4, 5, 8, 9, 11, 12 found in sample BNS-84-4.

Table 2. Virulence combinations and their frequencies (1984 isolates)

Virulence combination	Number of isolates
11	3
4,5,8,11	1
4,9,11,12	1
2,4,5,9,11	1
6,8,9,11,12	1
4,5,8,9,11,12	1
2,4,5,8,9,11,12	1

The 17 additional winter barleys included in the seedling tests comprised those cultivars on the NIAB Recommended List and those in recommended list trials. The frequency of virulence to these cultivars was very high, although cvs Pipkin, Pirate and Tipper did express a resistant reaction type to some of the isolates.

The suggestion has been made that cultivars carrying the Rhynchosporium resistance gene Rh^4 are also resistant to isolates of P.teres f. maculata (spotting form). A number of cultivars thought to carry this resistance gene were inoculated at the seedling stage with one such isolate, BNS-83-31. The results are given in Table 3. Cv. Sonja, included as a susceptible check, was the least susceptible, the remainder of the cultivars displaying a range of susceptibility.

Table 3. Standard test with isolate BNS-83-31 of seedling plants thought to carry the Rh^4 (Rhynchosporium) resistance gene

Cultivar	Level of infection*
Sonja	2
Corgi	3
15533 Co	3
C.I. 8256	3
Sergeant	4
Pipkin	4
La Mesita	4
Magnum	4
Osiris	5

* = 0 (completely resistant) to 5 (highly susceptible)

FIELD ISOLATION NURSERIES

Twenty-two winter and 19 spring barley cultivars were sown in each of two nurseries in 1983-1984, 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-83-14	4, 9, 10, 11, 12
BNS-83-31 (spotting type)	9, 11

Results

Infection levels within the winter cultivars was very low. This was attributable to the very dry spring and summer of 1984. No assessments were made on the winter barleys inoculated with isolate BNS-83-14, whilst the one score on winter cultivars inoculated with isolate BNS-83-31 was recorded very late in the season. This assessment and the results of the 1983 net blotch isolation nurseries are summarised in Table 4a. Higher levels of disease were observed on the spring cultivars, particularly within the nursery inoculated with isolate BNS-83-31 (Table 4b). Isolate BNS-83-31 which displayed spotting symptoms in glasshouse seedling tests (Clifford, del Buono & Jones, loc. cit.) also gave these same symptoms under field conditions.

The winter cultivars inoculated with the 'spotting' isolate are listed in order of ascending mean susceptibility (Table 4a). Comparison with the mean disease assessments of the 1983 nurseries shows a trend that as

cultivars become more susceptible to BNS-83-31 so they tend to become more resistant to the typical 'netting' isolates tested in 1983. This confirms seedling test results with BNS-83-31 when this isolate gave severe infection symptoms on cvs Tipper, Gerbel and Medallion, but a resistant reaction on the normally highly susceptible cv. Sonja. This isolate of P.teres f. maculata originated in Scotland. It is the form most commonly found in Denmark and it would thus appear to be particularly adapted to northern latitudes. The range of varietal responses observed and in particular the susceptibility of cv. Gerbel would seem to have relevance to Scottish winter barley cultivation. These are however the results of only one year's field tests and environmental conditions were unusual. Further tests will be carried out in the 1985 field season.

The spring cultivars showed a similar order of responses to the individual isolates including the spotting form. Cv. Triumph was one of the most susceptible as were cvs Tasman and Doublet, both of which have cv. Triumph as a parent. Cv. Acclaim which also has cv. Triumph in its parentage appeared to be slightly less susceptible to isolate BNS-83-31.

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Table 4a. Percent infection in net blotch isolation nurseries in 1983 and 1984

Cultivar	1984 BNS-83-31*	1983 BNS-82-5 and 38 (mean of 2 nurseries)
Winter cultivars		
Sonja	0	36
Pepite	0	21
Libra	0	-
Nevada	1	-
Halcyon	1	-
Panda	1	19
Igri	1	17
Impact	1	16
Pipkin	1	12
Metro	1	11
Opera	2	-
Natalie	2	-
Pirate	2	14
Maris Otter	2	14
Fenella	2	12
Athene	3	20
Fulmar	3	-
Vixen	5	13
Tipper	5	9
Monix	8	9
Gerbel	9	7
Medallion	10	13

* 1 scoring date, mean of 4 replicates

Table 4b. Percent infection in net blotch isolation nurseries in 1983 and 1984

Cultivar	1984 BNS-83-31*	1984 BNS-83-14*	1983 BNS-82-5 and 38 (mean of 2 nurseries)
Spring cultivars			
Patty	6	1	5
Golf	6	2	4
Vista	6	6	-
Atem	8	3	4
Golden Promise	9	6	-
Natasha	10	3	-
Koru	10	2	5
Midas	10	5	7
Apex	12	3	7
Efron	13	3	-
Acclaim	13	10	-
Roland	15	3	-
Themis	15	5	-
Klaxon	15	5	9
Kym	17	9	8
Triumph	17	11	13
Delta	18	5	7
Doublet	22	8	-
Tasman	25	11	21

* = mean of 2 scoring dates, 4 replicates

MILDEW OF OATS

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In a year with high levels of oat mildew a total of fifty-two samples were received mainly from trial sites, forty-one of which were successfully cultured.

The new spring oat cultivar Rollo was provisionally assigned to OMR group 2.

The most prevalent virulence combination was OMV 1+2+3 (race 5) attacking all resistances in present day commercial oats. The relative frequencies of OMV 1+2+3 (race 5) and OMV 1+2 (race 3) in 1984, i.e. 63% and 32% respectively, continued the trend apparent in 1982. Reversal of the values for these two races in the intervening 1983 season probably resulted from very restricted sampling due to low mildew incidence in that year. One sample was identified as OMV 1+3 (race 4) and one possessed virulence to the Avena barbata (OMR 4) resistance. The very simple and now rare OMV 1 (race 2) was not detected in 1984.

Adaptation to adult plant resistance was investigated in seven cultivars using detached leaf segments, inoculation being carried out directly in the field using a spore-trap. There was clear indication of adaptation in the mildew produced on the cv. Cabana to its own host, and a suggestion that some adaptation was also occurring to the high level of adult plant resistance in the cv. Rhiannon. The high level of resistance in Orlando was maintained.

SEEDLING TESTS WITH 1984 ISOLATES

Forty-two of the 52 samples of Erysiphe graminis avenae received in 1984 were from spring cultivars. The majority were from Wales (34 samples), the remainder coming from England, 9 from the South-west, 3 from the East and 6 from the East Central region. The 41 isolates which were successfully cultured were tested using methods described previously (Jones & Jones, 1980).

Results

The resistance grouping of all recommended spring and winter oat cultivars for 1985 are given in Table 1.

The resistance grouping of the provisionally recommended spring oat Rollo (RPB 515-79) has been determined as OMR 2, but confirmatory tests are required.

Table 1. Resistance groupings of cultivars on the 1985 NIAB Recommended List

OMR group	Differential cultivars	Recommended cultivars
0	Milford	Dula, Leanda
1	Manod	Peniarth(W), Pennal(W), Bulwark(W)
2	Cc 4146	Cabana, Trafalgar, Rollo*
3	9065 Cn 6/3/74	Avalanche
4	Cc 6490	-

* = New recommendation; (W) = winter oat

Details of the mildew samples tested are given in Table 2, and the frequency of occurrence of the various virulences detected in 1984 compared with the previous three years is shown in Table 3.

Table 2. Locations and cultivars from which viable mildew samples were received with virulences identified for each sample

Location	Cultivars	Virulences (OMV)
ENGLAND (East)		
PBI, Cambridge	Trafalgar	1 + 2 + 3
Newbury	Peniarth	1 + 2
NIAB, Cambridge	Pennal	1 + 2
ENGLAND (South-west)		
Seale-Hayne, Devon	Peniarth, Pennal, Panema, Avalanche	1 + 2 + 3
Netherexe, Devon	Cabana, Dula, Trafalgar	1 + 2
ENGLAND (East-central)		
Headley Hall, N.Yorkshire	Cabana, Leanda	1 + 2
	Dula, Saladin, Santana, Trafalgar	1 + 2 + 3
WALES		
Morfa Mawr, Dyfed	Milo, S.172, Cabana, Avalanche Dula, OM1105/21	1 + 2 + 3
	06618 Cn bc^4	1 + 2 + 3 + (4)*
Trawscoed, Dyfed	Orlando, Trafalgar, Saladin Santana, Dula	1 + 2
	Rollo	1 + 2 + 3
Powys	Dula	1 + 2
	Milo(2)+, Rhiannon(4)	1 + 2 + 3
Pembrokeshire, Dyfed	Milo	1 + 3
	Rhiannon(2), Milo(2)	1 + 2 + 3

*( ) = the reaction of this isolate on the differential cv. Cc 6490 (OMR 4) was not completely compatible

\+ = values in parenthesis after cultivar names indicate number of samples received of that cultivar

Table 3. Virulence group frequencies identified from samples received in 1984 compared with previous three years

Virulence group (race)	No. of isolates in 1984	Frequency (% total) 1981	1982	1983	1984
OMV 1 (2)	0	0	0	15	0
OMV 1 + 2 (3)	13	68	39	77	32
OMV 1 + 3 (4)	1	0	4	0	2
OMV 1 + 2 + 3 (5)	26	32	43	8	64
OMV 1 + 2 + 4 (6)	0	0	0	0	0
OMV 1 + 2 + 3 + 4 (7)	1	0	14	0	2
Number of isolates tested	41	47	28	13	41

The frequency of OMV 1 + 2 (Race 3) showed a decline in 1984 compared with the previous year, while the more complex OMV 1 + 2 + 3 (Race 5) showed an increase (Table 3), their frequencies reverting to approximately the 1982 values. The more widely virulent combination is able to attack cultivars in OMR group 2 (Trafalgar, Cabana and Maris Tabard) and in OMR group 3 (Avalanche, Milo, Pinto spring oats and Panema winter oat) as well as the OMR 1 cultivars Peniarth, Pennal and Bulwark winter oats. The combined virulence in the more complex race is being selected for in preference to the simpler OMV 1 + 2 (Race 3) combination, probably because the former is also able to attack the recently released cultivars in group OMR 3.

The virulence combination OMR 1 + 3 (Race 4) was found in one isolate, from a leaf sample of the cv. Milo (OMR 3). The remainder of samples received from cultivars with the corresponding resistance factors (OMR group 3), namely, Panema, Avalanche and Milo were infected with the more complex OMV 1 + 2 + 3 (race 5).

Virulence to Avena barbata resistance (OMR 4) was identified in one sample of a breeder's line carrying that resistance, received from a trial site. Tests did not show complete compatibility on the differential Cc 6490, the reaction being of a type 3, i.e. showing slight necrosis associated with the moderately sporulating pustules. This isolate also had virulences 1, 2 and 3 combined with 4 (Table 2), thus making it capable of attacking all commercial cultivars.

The least virulent OMV 1 (Race 2) was not detected in 1984. Only a few samples were received from cultivars which might be expected to be attacked by this race i.e. OMR group 0, such as Leanda and Saladin and also cultivars of group OMR 1, such as Peniarth and Pennal.

ADULT PLANT TESTS

Tests were carried out, as in 1982 and 1983, to investigate whether adaptation to adult plant resistance was occurring in the mildew populations developed on various cultivars grown under field conditions. The Schwarzbach spore-trap was used to collect spores from field plots of cvs Selma, Mostyn, Milo, Rhiannon, Avalanche, Orlando and Cabana on

27 June, 1984 (approx. G.S. 59), when emergence of the panicles was complete. The spores were deposited on detached, mildew-free leaf segments of the above seven cultivars, which had been grown in a spore-proofed glasshouse. The segments were placed on Benzimidazole Agar in polystyrene boxes, which were fixed temporarily to the base of the spore-trap for each collection. Each box contained two blocks of the seven test cultivars randomised differently and two boxes (total of four blocks) were used for each inoculum source. The inoculated leaf segments were incubated under a controlled environment of 10 ± 2°C and 12 h photoperiod, and on 5 July, after 8 days, the percentage leaf segment area showing mildew was recorded. Further details of the method used were given in Jones & Jones (1984).

Results and Discussion

Mean values for percentage leaf segment area covered with mildew are presented in Table 4. Means after analysis of variance of the logit transformation of the original values are given in Table 5, together with LSD values at P = 0.05 level of probability, unless otherwise stated. Selma, a highly susceptible cultivar with no known hypersensitive race-specific resistance (OMR 0) was used as a control. As a test cultivar it showed generally high levels of mildew relative to most of the other test cultivars, its overall mean value of 17.89% (Table 4) being significantly higher (Table 5) than the other cultivars including Cabana.

Of the seven isolates, the one from Cabana showed the greatest level of 'own host' adaptation; the value of 45% infection being significantly higher than the 22.5% recorded on Selma (Tables 4 and 5).

Mildew from Orlando, another OMR 2 cultivar, also produced a high infection level on Cabana (31.2%) indicating that the latter cultivar has relatively little residual resistance to mildew possessing corresponding virulence to its specific factor (OMR 2).

In contrast, the mildew from Orlando produced only 1.2% on the Orlando test cultivar, confirming the results of the previous year, indicating that its partial resistance has remained effective.

The mildew isolates from the four cultivars with specific factor OMR 3 do not show such marked adaptation as that shown by Cabana, when challenged with mildew having corresponding virulence to their specific resistance factor. As in 1983, the test cultivar Rhiannon showed very high levels of partial resistance to all isolates (overall mean of 2.82% - Table 4). However, in this experiment, when inoculated with mildew from a Rhiannon plot it showed a marked increase in susceptibility. However, the value of 11.8% is not significantly higher than those of the other OMR 3 cultivars in that column when logit values are compared (Table 5). Nevertheless, when Rhiannon was inoculated with mildew from Mostyn, Milo and Avalanche it developed only 0.2%, 0.2% and 1.8% mildew respectively (Table 4), values that are significantly lower (Table 5) than 11.8% suggesting some adaptation to Rhiannon's high level of adult plant resistance.

There is no clear indication this season of adaptation in the mildew population produced on the other three cultivars of this group, namely, Mostyn, Milo and Avalanche. There are differences in the infection

Table 4. Percentage leaf segment area infected with mildew using detached leaf segments from leaf 5 of the test cultivars (means of four blocks)

Test cultivars		Inoculum source (isolates) Selma (OMR 0)	Mostyn (OMR 3)	Milo (OMR 3)	Rhiannon (OMR 3)	Avalanche (OMR 3)	Orlando (OMR 2)	Cabana (OMR 2)	Mean
Selma	(OMR 0)	25.0	13.8	9.5	10.2	25.0	19.2	22.5	17.89
Mostyn	(OMR 3)	6.2	11.8	2.8	12.5	22.5	4.2	3.5	9.07
Milo	(OMR 3)	3.2	8.8	4.5	6.8	25.8	2.0	5.2	8.04
Rhiannon	(OMR 3)	4.2	0.2	0.2	11.8	1.8	0.5	1.0	2.82
Avalanche	(OMR 3)	1.2	4.8	5.2	6.2	11.8	2.0	0.8	4.57
Orlando	(OMR 2)	1.2	2.2	1.0	0.8	2.8	1.2	7.2	2.36
Cabana	(OMR 2)	5.2	2.5	0.2	4.2	12.2	31.2	45.0	14.39
Mean		6.64	6.29	3.36	7.50	14.54	8.64	12.18	

Mean of 7 'own host' or homologous means = 15.87; Mean of 42 'other' or heterologous means = 7.20

Table 5. Percentage leaf segment area infected with mildew (x) using detached leaf segments from leaf 5 of the test cultivars (means of four blocks) (Logit transformation x + 1.0)

Test cultivars		Inoculum source (isolates) Selma (OMR 0)	Mostyn (OMR 3)	Milo (OMR 3)	Rhiannon (OMR 3)	Avalanche (OMR 3)	Orlando (OMR 2)	Cabana (OMR 2)	Mean (LSD=±0.301)
Selma	(OMR 0)	-1.05	-1.97	-2.20	-2.15	-1.05	-1.46	-1.18	-1.58
Mostyn	(OMR 3)	-2.56	-2.14	-3.32	-2.00	-1.21	-3.14	-3.09	-2.49
Milo	(OMR 3)	-3.22	-2.67	-2.86	-2.51	-1.05	-3.55	-2.78	-2.66
Rhiannon	(OMR 3)	-3.08	-4.42	-4.42	-2.10	-3.71	-4.32	-4.18	-3.75
Avalanche	(OMR 3)	-3.86	-2.98	-2.78	-2.59	-1.96	-3.61	-4.24	-3.15
Orlando	(OMR 2)	-3.86	-3.60	-3.96	-4.07	-3.32	-3.86	-2.58	-3.61
Cabana	(OMR 2)	-2.72	-3.60	-4.42	-2.96	-2.10	-0.76	-0.16	-2.39
Mean (LSD=±0.301)		-2.91	-3.05	-3.42	-2.62	-2.06	-2.96	-2.60	

LSD to compare inoculum source/test cultivar means
= ±0.797 (P = 0.05), ±1.05 (P = 0.01), ±1.338 (P = 0.001)

Mean of 7 'own host' or homologous means = -2.84 ± 0.109 (n = 28);
Mean of 42 'other' or heterologous means = -2.80 ± 0.044 (n = 168); DF to test difference = 144

levels of OMR 3 cultivars when inoculated by isolates from other OMR 3 hosts. This may be due to variation in the level of inoculum sampled from the source cultivars. There is no evidene available at present to suggest that some of the OMR 3 cultivars have additional major factors for resistance, but further tests will be conducted in 1985 to examine this possibility.

Although the overall mean of the 'own host'or homologous combinations (15.87%) is considerably higher than the mean of 7.20% for the heterologous combinations (Table 4) the corresponding means for the logit values (Table 5) are not significantly different. There are, however, clear differences between cultivars in the magnitude of the adaptive response, and as Caten (1974) pointed out, this indicates a race non-specific component in those cultivars showing least erosion of their partial resistance.

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CROWN RUST OF OATS

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Only two samples of oat crown rust from the spring oat cvs Milo and Rhiannon were received in 1984 both of which were from Dyfed, Wales. Isolates of Puccinia coronata avenae were cultured from the leaf samples. Seedling tests on the 10 differential cultivars identified the isolate cultured from cv. Rhiannon (CRS-84-2) as being race 417. This virulence combination is compatible with the differential cvs Appler, Bond and Landhafer. This race has not previously been identified from samples received in the UK CPVS. The second isolate from cv. Milo (CRS-84-1) was avirulent on the differential cvs Anthony, Victoria and Ukraine and gave a mixed, mainly resistant reaction on cv. Trispernia. Cv. Santa Fe was not fully compatible with the isolate, a reaction type 2 being recorded. This particular virulence combination has not, to date, been assigned a race number. Further tests to confirm this virulence combination will be conducted prior to assigning a new race number.

VARIETY DIVERSIFICATION SCHEMES FOR WINTER WHEAT AND SPRING BARLEY, 1985

Variety diversification schemes to reduce the spread of disease in winter wheat and spring barley have been produced by the UKCPVS Committee since 1975. The two schemes following are 1985 versions which 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 variety mixtures. 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 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 1985

Severe infections may result if yellow rust or mildew spreads from an adjacent winter wheat crop into a variety with a low level of resistance. This risk can be reduced by choosing varieties with high levels of resistance. Further benefit can be obtained by sowing adjacent fields with varieties chosen from different diversification groups as this reduces the spread of disease from one to the other. Similarly, varieties to be grown in the same field in successive years or in a seed mixture should be chosen from different diversification groups.

Diversification groups (DG) of current winter wheat varieties are given below.

DG 1A	DG 1E	DG 4C	DG 8B	DG 10F
Brock	Aquila	Armada	Galahad	Rapier
Renard	Flanders			
		DG 6F	DG 9B	DG 11F
DG 1B	DG 2B	Hobbit	Brigand	Moulin
Fenman	Hustler		Gawain	
	Virtue	DG 7D		DG 12B
DG 1C		Stetson	DG 10B	Longbow
Boxer	DG 3B		Avalon	
Mission	Norman	DG 7G		DG 13B
		Hammer		Brimstone

Choosing varieties to grow together

1) Decide upon first-choice variety and locate its DG number.
2) Find this number under 'Chosen DG' down left hand side of table.
3) Read horizontally across table to find the risk of disease spread for each companion DG.
4) Ensure that chosen varieties are not all susceptible to another disease.

Chosen DG	Companion DGs																
	1A	1B	1C	1E	2B	3B	4C	6F	7D	7G	8B	9B	10B	10F	11F	12B	13B
1A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1B	+	m	+	+	m	m	+	m	+	+	m	m	m	m	m	m	m
1C	+	+	m	+	+	+	m	m	+	+	+	+	+	m	m	+	+
1E	+	+	+	m	+	+	+	m	+	+	+	+	+	m	m	+	+
2B	+	m	+	+	ym	m	+	m	+	+	m	m	m	m	m	ym	m
3B	+	m	+	+	m	ym	+	m	+	+	m	m	m	m	ym	ym	m
4C	+	+	m	+	+	+	ym	m	+	+	+	+	+	m	m	+	+
6F	+	m	m	m	m	m	m	ym	m	m	ym	ym	ym	ym	ym	m	m
7D	+	+	+	+	+	+	+	m	ym	y	+	+	+	m	m	+	+
7G	+	+	+	+	+	+	+	m	y	ym	+	+	+	m	m	+	+
8B	+	m	+	+	m	m	+	ym	+	+	ym	m	m	m	m	m	m
9B	+	m	+	+	m	m	+	ym	+	+	m	ym	ym	ym	ym	m	m
10B	+	m	+	+	m	m	+	ym	+	+	m	ym	ym	ym	ym	m	m
10F	+	m	m	m	m	m	m	ym	m	m	m	ym	ym	ym	ym	m	m
11F	+	m	m	m	m	ym	m	ym	m	m	m	ym	ym	ym	ym	m	m
12B	+	m	+	+	ym	ym	+	m	+	+	m	m	m	m	m	ym	m
13B	+	m	+	+	m	m	+	m	+	+	m	m	m	m	m	m	ym

+ = good combination; low risk of spread of yellow rust or mildew
y = risk of spread of yellow rust
m = risk of spread of mildew

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN SPRING BARLEY 1985

Severe infections may result if mildew spreads from an adjacent barley crop into a variety with a low level of resistance. This risk can be reduced by choosing varieties with high levels of resistance. Further benefit can be obtained by sowing adjacent fields with varieties chosen from different diversification groups as this reduces the spread of disease from one to the other. Similarly, varieties to be grown in the same field in successive years or in a seed mixture should be chosen from different diversification groups.

Diversification groups (DG) of current spring barley varieties are given below. Varieties in DG 0 are infected by all races of mildew and cannot contribute to diversification.

DG 0
Corgi
Golden Promise

DG 1
Apex
Atem

DG 2
Midas

DG 3
Candice
Flare
Georgie
Golf
Koru

DG 4
Goldmarker

DG 5
Javelin
Nairn
Natasha
Patty
Piccolo
Themis

DG 6
Tasman
Triumph

DG 7
Celt
Delta
Vista

DG 8
Efron
Roland
Tweed

DG 9
Doublet
Klaxon
Lina

DG 10
Egmont
Regent

DG 11
Kym

DG 12
Acclaim
Heriot

Choosing varieties to grow together

1) Decide upon first-choice variety and locate its DG number.
2) Find this number under 'Chosen DG' down left hand side of table.
3) Read horizontally across table to find the risk of mildew spread for each companion DG.
4) Ensure that chosen varieties are not all susceptible to another disease.

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

+ = good combination; low risk of spread of mildew
m = risk of spread of mildew
Only spring barley varieties with good mildew resistance should be grown adjacent to winter barley