U.K. CEREAL PATHOGEN VIRULENCE SURVEY

1987 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

Chairman: Mrs V Silvey, BSc, Dip Math Stat

Secretary: Dr R A Bayles, National Institute of Agricultural Botany,

Huntingdon Road, Cambridge, CB3 0LE

Tel: Cambridge (0223) 276381

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MEMBERS OF THE UK CEREAL PATHOGEN VIRULENCE SURVEY COMMITTEE, 1987-88

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Dr T L W Carver	Institute for Grassland & Animal Production, Welsh Plant Breeding Station, Aberystwyth
Dr N H Chamberlain	British Society of Plant Breeders
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Mr P L Stigwood	National Institute of Agricultural Botany, Cambridge
Mrs S E Slater	Institute of Plant Science Research, Cambridge Laboratory
Professor M S Wolfe	Institute of Plant Science Research, Cambridge Laboratory

CONTENTS

THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

OBJECTIVES

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

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

METHODS

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

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

Other sampling methods are also used including mobile nurseries and the wind impaction spore trap.

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

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

RESULTS

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

The information provided by the Survey is used in various ways. Isolates possessing new virulences are used by the National Institute of Agricultural Botany to evaluate the resistance of cereal cultivars in trial in England and Wales. These isolates are also used by plant breeders to select lines with effective forms of resistance. Isolates are also supplied to Universities and Colleges for research projects and teaching purposes. Versions of the cultivar diversification schemes, modified to meet regional requirements, are published in the National Institute of Agricultural Botany Farmers Leaflet No. 8 'Recommended varieties of cereals', the Scottish Agricultural Colleges leaflet 'Recommended varieties of cereals', and by the Agricultural Development & 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 1987

Mildew of wheat

Pathogenicity for cultivars with mildew resistance from the wheat-rye translocation (WMR 7) appears to be increasing in frequency.

The wheat mildew pathogen was less sensitive to azole fungicides than previously, but this change appeared to be restricted to the southern part of the country.

Yellow Rust of Wheat

The frequency of the virulence WYV 6 remained high, despite the decline in popularity of cultivars possessing the corresponding resistance, WYR 6 (e.g. Longbow, Norman). Virulence combinations are continuing to increase in complexity. The virulence type WYR 1,2,3, which dominated the yellow rust population in the late 1970's and early 1980's, has now been replaced by more complex types, such as WYV 1,2,3,6 and WYV 1,2,3,4,6.

Brown Rust of Wheat

The winter wheat cultivars Fortress, Apollo and Rocket possess WBR-1, derived from rye (Secale cereale). Hornet, like cv. Slejpner also possesses this resistance but with additional adult plant resistance. The spring cv. Wembley appears to have either WBR 3 or WBR 4, a temperature-sensitive resistance which is more effective at lower temperatures.

Mildew of barley

There was a further increase in the frequency of complex recombinants of the pathogen caused by cultivation of hosts with combinations of previously exposed resistance genes.

The occurrence of pathogen recombinants with reduced sensitivity to all three major fungicide groups in 1986 and 1987 was confirmed in tests with single colony isolates.

In N. Ireland pathogenicity levels generally were more akin to 1985 than 1986. The most obvious features were drops in BMV's 3,5 and 3,4. Levels of BMV 6b,c ceased to rise. There was a low level of pathogenicity to BMR 4,9 (cv Atem).

Yellow Rust of Barley

All isolates from the 1987 survey possessed BYV 1 and BYV 2, but there appears to have been a decrease in the frequency of BYV 3 (virulence for Triumph).

Brown Rust of Barley

The spring barley cv. Corniche appears to have the Triumph resistance (BRR 10), but also carries additional resistance which is effective at the adult plant stage to Triumph-virulent isolates. Adult plant tests showed the winter barley cultivars to display a range of quantitative responses whilst the spring cultivars were shown to carry a number of specific resistances.

Rhynchosporium of Barley

Forty six percent of 1987 isolates carried virulence to cv. Pirate, an increase of ca. 100% over the two previous years. The resistance of the spring barley cv. Digger remained effective to all isolates at the seedling stage but showed low levels of infection in one of the adult plant isolation nurseries, probably due to the sheer volume of inoculum. Joline (BRR?) has a specific resistance effective against Octal race 0.

Net Blotch of Barley

Seedling tests with 1987 isolates showed high frequencies of virulence to winter barley cultivars on the NIAB Recommended List of Cereals or in Recommended List Trials. Cultivar Marinka which was resistant to all isolates tested in 1985 and 1986 was susceptible to 19 (80%) isolates in 1987. This appears to be due to a significant change in virulence in the pathogen population.

Mildew of Oats

The trend observed in recent years of OMV 1,2,3 (race 5) increasing in prevalence continued in 1987. The simpler race 3 (OMV 1,2) which is unable to attack cultivars with OMR 3 resistance such as Rollo, Avalanche and Panema has declined to a frequency of 15% as the hectarage of these OMR 3 cultivars increases.

Crown Rust of Oats

The one isolate of crown rust received was identified as race 251, which occurs commonly in the UK.

MILDEW OF WHEAT

M S Wolfe and Susan E Slater

Institute of Plant Science Research (Cambridge Laboratory)

Pathogenicity for WMR 7 appears to be increasing in frequency; the pathogen populations obtained from WMR 7 cultivars were relatively complex. However, the most complex recombinants were obtained in populations from the spring cultivar Axona (possibly WMR 2,4,5,6,8 and Sona).

The intermediate resistances of WMR 8 and cv. Talent may be matched in populations from those cultivars but the pathogenicity characters were not common in populations from other cultivars.

Wheat mildew became less sensitive to azole fungicides in 1987, but the change appeared to be restricted to the south of the country. The wheat mildew pathogen appears to be less sensitive than the barley mildew pathogen to morpholine fungicides in laboratory tests.

Epidemiological comparisons

Colony counts on untreated seedlings of barley and wheat were compared at different dates for two WIST journeys, Cambs. being a circuit of the city and E. Anglia being a circuit to the east and south (Table 1).

Table 1. Colony counts on untreated WIST seedlings compared for species and sites

	Apr 8/9	Apr 22/3	May 13/5	May 26/7	Jun 10/1	Jun 17	Jun 24	J/J 30/1
Cambs.								
Barley	10	27	9	67	16	10	-	108
Wheat	103	44	3	110	10	9	-	125
E. Anglia								
Barley	4	27	4	135	5	-	49	33
Wheat	14	32	9	158	3	-	87	59

Except for the high value for wheat in early April in Cambs., the barley and wheat values were highly correlated, indicating that WIST catches are more dependent on weather conditions that favour spore release than on differences between epidemic cycles on barley and wheat or between nearby sites.

Similar data from two sites at Bristol showed first, that the season for spore production was longer in Bristol in 1987 compared with that in the Cambridge area. Second, more spores were caught at 25m above ground than at ground level in Bristol, probably because more air passed over the nurseries exposed at the greater height during the same period of exposure.

Population structure and dynamics of pathogenicity characters

The differential cultivars and their resistance phenotypes are given in Table 2.

Table 2. Wheat mildew resistance (WMR) group definitions, differential cultivars and known resistance genes

WMR group	Gene	Cultivar
0	-	Cerco, Moulin, Jerico, Minaret, Alexandria
2	Pm2	Galahad, Fenman, Longbow, Norman, Avalon
4	Pm4b	Armada
5	Pm5	Hope
7	Pm8	Ambassador, Corinthian
8	Mli	Mercia, Aquila
2,6	Pm2,6	Brimstone
2,7		Hornet
4,8		Mission
2,4,6		Rendezvous
2,6,7		CWW 1645/5
2,6,8		Parade
2,Talent		Brock
7,?		Slejpner
5,8,x		Tonic
5,8,y		Broom
Sona		Wembley
Axona		Axona

Bulk isolates from a range of cultivars growing in field trials were tested on the differential cultivars (Table 3). Pathogenicity for WMR 2 and 6 is widespread and common in the population and so individual values have been omitted; only values on cv. Brimstone (WMR 2,6), are shown.

In Table 3, the mean values for tests of populations from the common cultivars Avalon and Galahad are given as an indication of the average population structure in the country. From these values, it is evident that pathogenicity on WMR 7 is becoming common. It is also notable that the populations from WMR 7 cultivars tend to have high values for a number of "unnecessary" characters. This often occurs with newly emerging sub-populations since the "unnecessary" characters may be important for survival of the newly selected characters on more common cultivars that do not carry WMR 7.

Also from Table 3, it appears that there is little interaction between source cultivar and pathogenicity for WMR 8, despite the relatively high colony counts on the WMR 8 differentials. This indicates that WMR 8 resistance is quantitative at the seedling stage and that it is matched by only a few of the populations from non-WMR 8 cultivars.

The differential cv. Tonic is protected from most of the populations pathogenic on WMR 8 because it also carries WMR 5. However, in the differential tests, cv. Tonic was particularly susceptible to the population obtained from cv. Tonic in the field, more so than other WMR 8 cultivars to their own matching populations. This indicates that WMR 8 may be less effective in cv. Tonic than in other cultivars.

In 1986, small differences were found in the resistances of cvs. Tonic and Broom when they were used as differentials. In 1987 they appeared to react almost identically to the populations tested and so only the data for cv. Tonic are given in Table 3. From the obvious correlation between the performance of cvs. Tonic and Axona as differentials, it is possible to suggest that cv. Axona may carry WMR 5 and 8 in addition, possibly, to the cv. Sona resistance. The population selected on cv. Axona appears to give rise to a dangerous recombinant form with pathogenicity for WMR 2,4,5,6,8 and cv. Sona.

Table 3. Mean pathogenicity values relative to values on cv. Cerco of isolates from plots of cultivars in trials

	Source cultivar	Brimstone 2,6	Armada 4	Rndzvs 2,4,6	Mission 4,8	Ambsdr 7	Hornet 2,7	Sljpnr 7,?	CWW 2,6,7	Mercia 8	Parade 2,6,8	Tonic 5,8,+	Axona Sona+	Wembly Sona	Brock 2,Tal.
0	Moulin	57	68	23	41	0	6	36	0	20	73	0	0	28	54
	Minaret	20	133	7	0	0	0	133	7	13	0	0	0	0	60
	Alexandria	51	30	66	59	0	0	0	0	31	96	0	0	29	61
2	Longbow	89	18	27	38	5	5	2	0	41	95	0	0	36	54
	Norman	78	59	72	64	20	14	3	11	38	78	0	0	4	55
	Fenman	93	69	121	107	0	0	0	3	17	93	0	0	0	21
2,6	Brimstone	75	54	80	54	0	0	1	0	43	104	1	0	27	56
2,4,6	Rndzvs	128	66	120	82	0	0	0	0	52	79	0	0	19	43
4,8	Mission	74	92	44	75	0	0	3	0	37	65	0	0	37	52
7	Hornet	81	32	62	38	124	124	106	113	88	66	0	0	6	70
	Mandate	40	54	0	49	102	125	77	35	54	70	0	0	0	54
	Rocket	86	19	18	18	70	67	41	41	80	59	0	0	58	88
	Slejpner	102	68	70	62	110	90	89	92	52	117	0	0	3	52
	Apollo	44	92	53	64	67	51	67	36	17	52	0	0	11	57
8	Mercia	75	0	0	0	75	64	89	14	96	44	0	0	41	96
	Aquila	74	53	65	41	17	25	34	15	33	90	4	0	11	55
2,6,8	Parade	93	111	5	51	0	3	65	0	28	79	0	0	0	26
5,8	Tonic	90	73	37	26	0	0	42	2	16	64	102	30	0	43
	Cub	48	33	65	58	16	15	0	8	53	65	98	6	77	55
	Dollar	68	8	2	0	0	49	13	0	46	96	50	25	63	76
Sona	Axona	75	49	83	72	0	4	5	3	38	98	87	90	57	62
	Wembley	90	117	91	62	7	16	9	7	36	72	0	0	52	43
2,Tal	Brock	101	14	16	7	9	6	12	13	51	67	1	0	40	88
Means	Av./Gal.	92	43	37	46	37	29	33	21	35	90	2	0	25	51
	non-match.	69	55	46	45	8	12	25	5	42	75	5	3	25	56
	match.	99	79	120	75	95	125	89	-	44	79	83	90	52	88

As with WMR 8, the Talent resistance in cv. Brock is intermediate and matched only by the populations from cv. Brock itself and from one or two other cultivars.

Table 4. Comparison of pathogenicity of populations from the same host cultivars between 1986 and 1987

Source		Test cultivar and WMR group								
		Hrnt 2,7	Sljp 7,+	Mrca 8	Misn 4,8	Prde 2,6,8	Tonc 5,8+	Axna Axna	Wmby Sona	Brk 2,Ta
Hrnt	86	62	27	46	6	18	0	0	12	69
	87	124	106	88	38	66	0	0	6	70
Sljp	86	32	25	28	32	53	0	0	0	46
	87	90	89	52	62	117	0	0	3	52
Mrca	86	7	2	52	38	55	8	0	18	37
	87	64	89	96	0	44	0	0	41	96
Tonc	86	0	0	32	94	71	14	12	32	43
	87	0	42	16	26	64	102	30	0	43
Wmby	86	6	0	46	71	61	1	0	54	57
	87	16	9	36	62	72	0	0	52	43
Brck	86	8	8	33	42	48	2	0	14	31
	87	6	12	51	7	67	1	0	40	88

Table 4 provides a comparison of data on pathogenic specialisation between 1986 and 1987. From this Table, it appears that there was a general increase in both matching and non-matching pathogenicity, with the exception of the decrease in pathogenicity for cv. Mission among populations from non-WMR 7 cultivars. However, the methods used to obtain the data differed between years. The 1986 data represent the means of values obtained from samples of single colonies obtained on susceptible wheat seedlings exposed in the WIST. The 1987 data, on the other hand, were obtained from field trial plots as bulk isolates and may have been more influenced by inter-plot interference and selection of complex phenotypes. Nevertheless, it will be most important to follow the relevant populations in 1988 to determine whether or not real shifts to increased complexity are occurring in the pathogen population.

Triadimenol insensitivity in wheat mildew

Table 5 illustrates the changing response of the pathogen to the azole fungicides.

Table 5. Changes with time of the relative frequencies of colony counts on wheat seedlings treated with different amounts of triadimenol (E. Anglia)

Rate g a.i. kg^{-1}	1983	1984	1985	1986	1987
0.125	18	33	32	49	80
0.250	-	-	14	25	57
0.375	-	-	5	14	41

In contrast with the barley mildew pathogen (q.v.) there appears to have been a marked increase in insensitivity of the wheat mildew pathogen to triadimenol from 1986 to 1987. However, from comparisons made over a wider area, it is possible that this increase was restricted to the southern part of the country (Table 6).

Table 6. Geographical distribution of insensitivity to triadimenol in wheat and barley mildew in 1987

Region	Fungicide rate (g a.i. kg^{-1}) 0.025		0.250		0.375	
	Wht	Brl	Wht	Brl	Wht	Brl
E. Angl.	71	68	21	61	19	30
Cambs	80	81	56	33	41	26
E. Mids.	16	111	3	9	3	9
N. Engl.	37	30	10	30	10	30

For both pathogens, the decline in insensitivity during the season appeared to be more marked than in previous seasons (Table 7).

Table 7. Change in insensitivity to triadimenol during the 1987 season (0.375 g a.i. kg^{-1})

Month	Wheat mildew Cambs.	E. Angl.	Barley mildew Cambs.	E. Angl.
April	36	36	22	40
May	78	15	40	34
June	10	7	15	17

Insensitivity of wheat mildew to morpholines

Comparative data for wheat and barley mildew obtained from the WIST in 1987 indicate that the wheat mildew pathogen is less sensitive to morpholine fungicides (Table 8). Unfortunately, there are no data available to show whether or not the relatively high values for wheat mildew represent an increase over previous seasons.

Table 8. Comparison of the sensitivity of the wheat and barley mildew pathogens to morpholine fungicides (rates as proportion of field rate)

	tridemorph(1/20) wheat	barley	fenpropimorph(1/100) wheat	barley
E. Anglia	106	27	15	11
Cambs.	-	27	-	4
E. Mids.	62	23	76	23
N. Engl.	67	4	43	0

During the season, the peak for morpholine insensitivity was reached at the end of June, which is consistent with the use of morpholines only as foliar sprays.

YELLOW RUST OF WHEAT

R A Bayles, M H Channell and P L Stigwood

National Institute of Agricultural Botany

76 samples were received in 1987. The frequency of WYV 6 remained high whilst that of WYV 4 and WYV 1,4 decreased. Complex virulence combinations have become more common over the past 10 years. In early years, the majority of isolates possessed WYV 1,2,3, but these have now been replaced by isolates of the WYV 1,2,3,6 and WYV 1,2,3,4,6 types. The implications of increasing complexity of virulence for cultivar diversification are examined.

INTRODUCTION

The principal aim of the wheat yellow rust survey is to detect increased virulence for specific resistances to Puccinia striiformis, both of the overall and adult plant types. At the same time, specific resistances present in current and new cultivars are identified and the information used to construct a varietal diversification scheme. Specific resistances (WYR factors) identified in wheat cultivars to date, the resistance genes where known, differential cultivars possessing each resistance and the year of first detection of virulence (WYV) in the UK population of P.striiformis are given in Table 1.

Table 1 Resistance factors to Puccinia striiformis and differential cultivars.

WYR Factor	Gene	Type*	Differential Cultivar(s)**	WYV detected
WYR 1	Yr 1	O	Chinese 166, Maris Templar	1957
WYR 2	Yr 2	O	Heine V11, Brigand	1955
WYR 3	Yr 3a + 4a	O	Vilmorin 23, Cappelle Desprez	1932
WYR 4	Yr 3b + 4b	O	Hybrid 46, Avalon	1965
WYR 5	Yr 5	O	T. spelta album	
WYR 6	Yr 6	O	Heines Kolben, Maris Ranger	1958
WYR 7	Yr 7	O	Lee, Tommy	1971
WYR 8	Yr 8	O	Compair	1976
WYR 9	Yr 9	O	Riebesel 47/51, Clement	1974
WYR 10	Yr 10	O	Moro	
WYR 11	-	A	Joss Cambier	1971
WYR 12	-	A	Mega	1969
WYR 13	-	A	Maris Huntsman	1974
WYR 14	-	A	Hobbit	1972
Additional test cultivars 1987				
WYR 1,2,4			Brimstone	
WYR ?			Hornet	
WYR (R)			Parade	
WYR (R)			Mandate	
WYR (?)			Fortress	

* O = Overall A = Adult Plant. Overall resistances are effective at all growth stages, adult plant resistances are ineffective at seedling growth stages.

** Differential cultivars used in 1987 seedling tests are underlined.

METHODS

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

1987 isolates

In 1987, yellow rust reached high levels in many areas in the East of the country. Seventy six samples were received, these being collected from commercial crops, field trials and disease observations plots in East and North East England and Scotland.

Isolates were made from 52 samples. Seedling virulence tests, using the differential cultivars indicated in Table 1, were carried out.

Adult plant tests

Infection failed to develop to satisfactory levels in adult plant tests in Polythene tunnels due to abnormally high temperatures in the period immediately following inoculation.

RESULTS

The survey is not a random population sample and changes in virulence frequency from year to year (Table 2) should therefore be interpreted with caution.

Table 2 Virulence factor frequency (%)

WYV Factor	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
WYV 1	73	73	83	95	71	63	85	75	76	78	87
WYV 2	100	97	100	100	100	100	100	100	100	100	100
WYV 3	100	100	100	85	95	100	100	100	100	100	100
WYV 4	24	27	17	15	29	37	20	31	45	70	47
WYV 5	0	0	0	0	0	0	0	0	*	*	*
WYV 6	16	26	17	25	31	29	26	64	90	96	89
WYV 7	8	0	0	0	5	5	0	3	3	22	8
WYV 8	4	0	0	0	0	2	0	0	*	*	*
WYV 9	0	0	0	0	5	2	23	31	3	4	5
WYV 10	0	0	0	0	0	0	0	0	*	*	*
Additional Cultivars 1987											
Brimstone WYR 1,2,4								3	10	61	34
Hornet WYR 9+?								*	*	0	2
Parade WYR ?								*	*	0	0
Mandate WYR ?											0
Fortress WYR (?,1,4)											0
No of isolates tested	26	66	30	20	42	41	63	36	29	23	52

* = differential not included in test

The frequency of WYV 6 remained high in 1987 despite the continued decline in popularity of WYR 6 cultivars. There was a decrease in the frequency of WYV 4 to 1985 levels, but, as in 1986, the majority of WYV 4 isolates were also virulent on Brimstone (WYR 1,2,4), showing that the combination WYV 1,4 has now become common.

Figure 1 shows the frequency of combinations of overall virulence factors detected in seedling tests over the past 10 years. The four dominant combinations have been WYV 1,2,3, WYV 1,2,3,6, WYV 1,2,3,4,6 and WYV 2,3,4,6, with WYV 1,2,3,9 achieving prominence in 2 years. Other combinations occurred intermittently at low frequencies. Isolates with the simple combination WYV 1,2,3, which comprised around 70% of the annual sample in the late 1970's and early 1980's, have now been entirely replaced by more complex isolates, reflecting the increased popularity of cultivars with the resistance factor combinations WYV 1,2,3,6 and WYR 1,2,3,4 in the early to mid 1980's. The frequency of WYV 2,3,4,6 has remained relatively constant but shows some evidence now of being displaced by the more widely virulent isolate WYV 1,2,3,4,6.

A trend towards increasing complexity of virulence combinations in the yellow rust population will reduce the scope for effective cultivar diversification. Fig 2 shows changes in the national popularity of cultivars in the main WYR groups which form the basis of the diversification scheme. In the early years of the scheme, the majority of those cultivars which did not possess good adult plant resistance to all isolates (i.e. were not in DG 1) were protected by a specific adult plant resistance, most commonly WYR 13 or WYR 14, and could be allocated to separate diversification groups accordingly. The overall specific resistance WYR 6 also provided an effective barrier to the spread of infection between groups. More recently however, with the increasing complexity of specific resistance combinations in cultivars and corresponding changes in the virulence of the pathogen, diversification groups have come to depend upon combinations of overall and adult plant specific resistances. Unfortunately, it is not possible to test all isolates for adult plant virulence. Those which are tested are not selected at random, but because it is thought that they may display new virulence characteristics. However, a review of the virulence composition of isolates included in adult plant tests since 1978 shows which combinations of overall and adult plant virulences have been identified and which still remain undetected (Table 3).

Table 3

Combinations of adult plant virulences and overall virulences detected in adult plant tests 1978 - 1986.

WYV Factors	Number of isolates
1,2,3,13	6
1,2,3,14	2
1,2,3,6,13	12
1,2,3,4,6,13	2
2,3,4,14	2
2,3,4,6,14	3
2,3,4,6,13,14	4
2,3,4,6,12,13,14	1
2,3,4,6,12	1
1,2,3,9,13	3
2,3,4,8,9,12	1

The two most widely grown groups of cultivars over the past three years have been those with resistances based on WYR 4,14 and WYR 1,14 (Fig. 2). To date, no isolate with combined virulence for the two groups (WYV 1,4,14) has been detected, although the WYV 1,4 combination is now common in the form WYV 1,2,3,4,6 (Fig. 1). The addition of WYV 14 to isolates of this type would result in an isolate capable of infecting over 40% of the winter wheat acreage for 1988. This represents over 80% of the acreage dedicated to non-DG 1 cultivars and would impose severe constraints upon options for diversification.

The only other specific resistance group of any significance is that based on WYR 9, which has increased to around 14% with the commercialisation of the cultivar Slejpner. This provides a useful increase in diversity, although it cannot be predicted how readily WYV 9 will combine with other critical virulences. It appears that, unless new sources of specific resistance can be found and utilised, high levels of non-specific or background resistance, such as that found in DG 1 cultivars, will become increasingly vital in limiting spread of yellow rust.

Fungicide Insensitivity

In September 1987 an investigation of fungicide insensitivity in yellow rust of wheat and barley started at NIAB, funded by the Home-Grown Cereals Authority. The main aims will be to establish current levels of insensitivity to the major fungicides used in the control of yellow rust and to determine whether any changes have taken place since the early years of the yellow rust survey. The situation will be monitored during the coming 3 seasons and comparisons made between isolates collected from fungicide-treated and untreated crops. Initial work has concentrated on developing the relevant screening techniques, using seedlings sprayed with a range of concentrations of representative chemicals. Testing of early isolates is now underway.

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Figure 1. Frequency of combinations of overall virulence factors detected in seedling tests, 1978-1987.

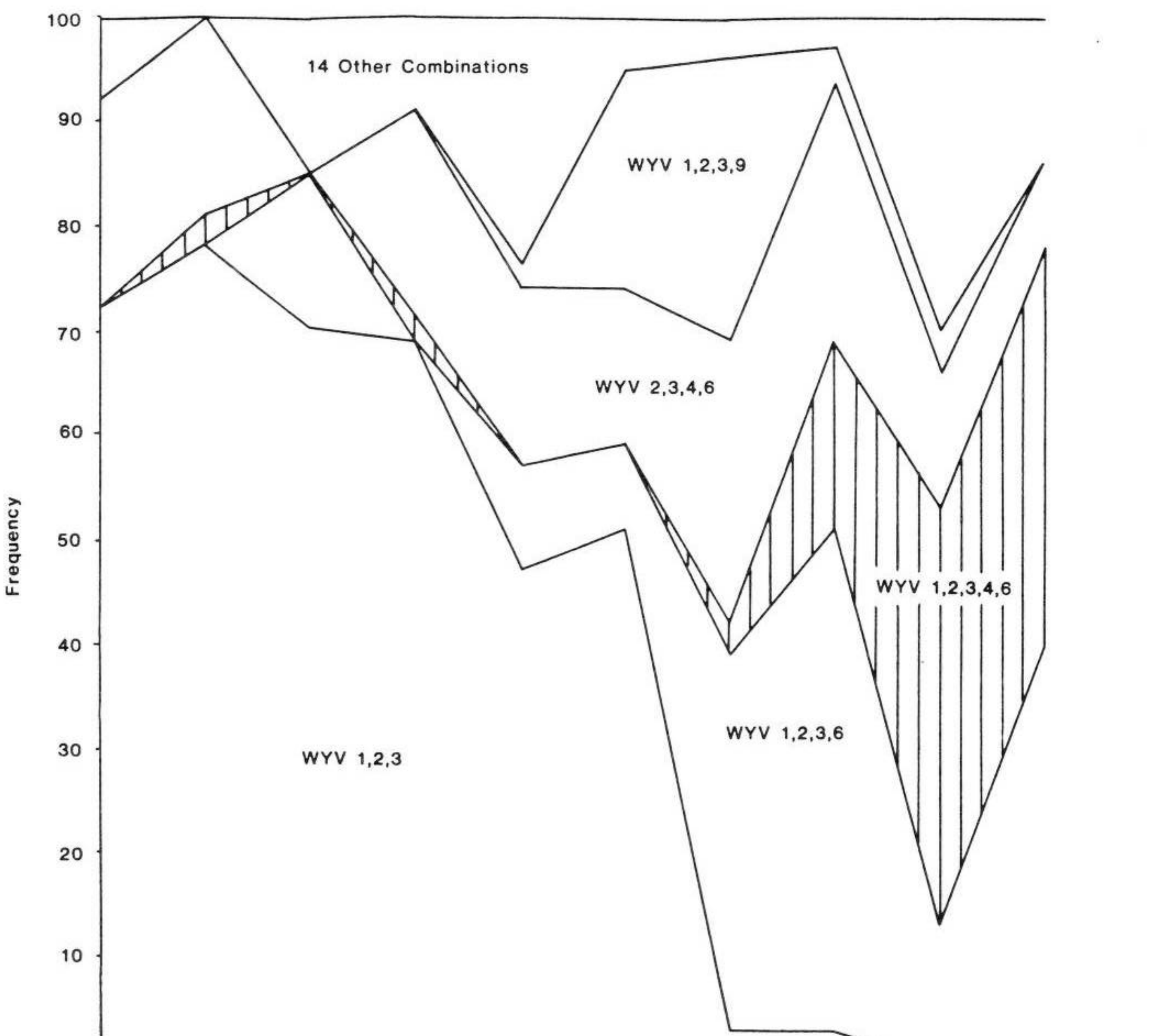
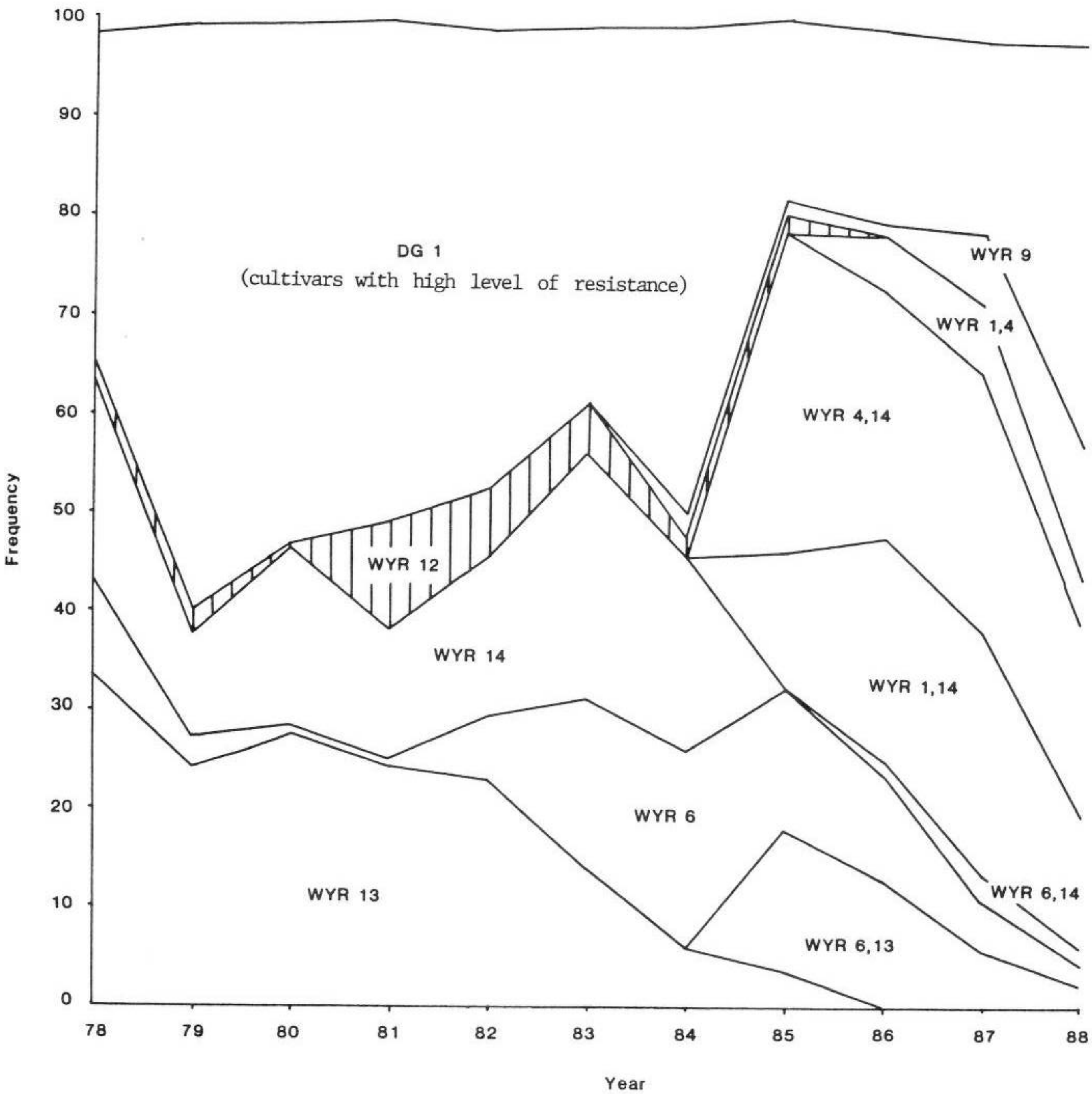


Figure 2. Popularity of cultivars in the main WYR groups, 1978-1987 (from seed production statistics).



BROWN RUST OF WHEAT

E.R.L. Jones & B.C. Clifford

Institute for Grassland and Animal Production,
Welsh Plant Breeding Station, Aberystwyth

Isolates of Puccinia recondita were tested from 36 of the 48 samples received in 1987. These included 18 isolates received from the HGCA-funded MAFF Cereal Survey, to be further screened at ESCA for fungicide insensitivity. The winter wheat cv. Slejpner appears to carry WBR-1 plus additional adult plant resistance. The spring cv. Wembley appears to have either WBR-3 or WBR-4, a tempertature-sensitive resistance which is more effective at lower temperatures. Adult plant field tests identified several new spring and winter wheat cultivars with effective resistance to isolate WBRS-86-9 (WBV-2,3,4,6,9) and to isolate WBRS-86-11 (WBV-1,2,6).

SEEDLING TESTS WITH 1987 ISOLATES

Forty-eight samples of Puccinia recondita were received in 1987. This number included 18 sent from the MAFF Cereal Survey specifically for fungicide insensitivity screening at E.S.C.A. (Dr. J. Gilmour, HGCA funded project). All the leaf samples were from winter wheat cultivars, the majority coming from the south of England (32) and the east of England (12). The remainder came from Eire (2), Wales (1), and the west-central region of England (1). Isolates were obtained from 36 of the samples and were tested on differential cultivars which comprised the standard WBR reference cultivars, cv. Thatcher backcross lines carrying different resistance factors, and 13 other spring and winter wheat cultivars from the NIAB Recommended List and Recommended List trials (Table 1). The tests were carried out under two post-inoculation environments; a low-temperature regime (10°C and 12 h photoperiod) and a high temperature regime (25°C and 12 h photoperiod).

Table 1. Differential cultivars

Standard differential cultivars		Thatcher Lr lines	Spring and Winter cultivars
Clement	(WBR-1)	Lr 1	Axona
Maris Fundin	(WBR-2)	Lr 2a	Minaret
Norman	(WBR-2)	Lr 3	Jerico
Hobbit	(WBR-2)	Lr 3bg	Wembley
Sappo	(WBR-3)	Lr 3ka	Alexandria
Maris Halberd	(WBR-4)	Lr 9	Cub
Gamin	(WBR-6)	Lr 15	Dollar
Sterna	(WBR-7)	Lr 19	Galahad
Sabre	(WBR-7)	Lr 24	Slejpner
Armada	(WBR-0)		Mercia
			Brimstone
			Longbow
			Brock

Results

Isolate/cultivar interactions were assessed on the standard 0-4 scale and classified as resistant (R:0-2) or susceptible (S:3-4). In cultivars with temperature-sensitive resistance factors (WBR-2,3,4 and 7), interactions were classified as susceptible only if that reaction was expressed at both temperatures. The data are presented in Table 2.

Table 2. Classification of seedling reactions of differential cultivars to 1987 pathogen isolates

Cultivar	WBR factor	Virulence combination					Virulence frequency
Clement	1	R	R	S	R	S	0.11
Fundin	2*	S	R	S	S	R	0.78
Norman	2*	S	R	S	S	R	0.78
Hobbit	2*	S	R	S	S	R	0.78
Sappo	3*	R	R	R	S	R	0.08
Halberd	4*	R	R	R	S	R	0.08
Gamin	6	S	S	S	S	S	1.00
Sterna	7*	R	R	R	R	R	0
Sabre	7*	R	R	R	R	R	0
Armada	0	S	S	S	S	S	1.0
No. of isolates		22	7	3	3	1	

*Temperature sensitive

Four of the isolates were virulent on cv. Clement (WBR-1). Cultivar Slepjner was also only susceptible to the same four isolates, suggesting that it carries the same resistance gene. Adult plant tests have previously shown that Slepjner is resistant to WBV-1 isolates, suggesting that it has additional adult plant resistance.

The temperature-sensitive resistance WBR-2, present in cvs Fundin, Norman and Hobbit was effective against 9 of the isolates at both temperatures.

Three isolates gave a fully compatible reaction at both the high and low temperatures on the spring wheat cvs Sappo (WBR-3) and Halberd (WBR-4). The spring wheat cv. Wembley gave an identical pattern of response to the isolates tested, also being more susceptible at the higher temperature.

Cultivar Gamin (WBR-6) was susceptible to all the 1987 isolates. All the isolates gave a mixed resistant type reaction on cvs Sabre (WBR-7) and Sterna at 25°C. At 10°C several of the isolates gave a mixed susceptible reaction; confirming that this resistance is temperature-sensitive.

In Thatcher Lr backcross lines resistance conferred by Lr 1, Lr 3bg, Lr 9, Lr 19 and Lr 24 was effective at both temperatures against all the isolates tested. The temperature-sensitive resistance of Lr 2a was effective against 6 of the isolates tested; the winter cv. Brock showing a similar pattern of response to the same isolates.

One isolate, WBRS-87-7 gave a fully compatible reaction on Lr 3, the remaining isolates give a mixed reaction type of a mostly resistant nature.

The spring wheat cv. Cub has a temperature-sensitive resistance effective at 10°C but was overcome by the majority of isolates at 25°C. Cv. Jerico gave a resistant or mixed resistant reaction to the isolates at both temperatures. The temperature-sensitive resistance of cv. Axona was only effective against 3 of the isolates at 10°C. The spring cvs Minaret, Alexandria and Dollar, and the winter cvs Galahad, Mercia, Brimstone and Longbow were susceptible to all the isolates tested.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Two isolates were tested on adult plants in field isolation nurseries in 1987. The isolates used were:

Isolate	Origin and description
WBRS-86-9 (WBV-2,3,4,6,9)	CWW 4217/15, ex NL Trial, NIAB, Cambridge
WBRS-86-11 (WBV-1,2,6)	Soleil ex NL Trial, NIAB, Cambridge

Each nursery comprised 29 winter and 10 spring wheat cultivars, replicated three times. Assessments of percentage infection and reaction type were made throughout the season.

Results

These are summarised in Table 3. Reasonable levels of infection built up within the nurseries, although the spring cultivars within the nursery inoculated with isolate WBRS-86-11 were less heavily infected than those inoculated with isolate WBRS-86-9. Results confirmed the previous grouping of cultivars according to their resistance factors.

The winter wheat cvs Fortress, Aquila, Apollo and Rocket showed a similar pattern of response to the two isolates as did cv. Clement (WBR-1). Cv. Slejpner has also been placed in this group although it is resistant to both isolates in the field. Seedling tests confirm that this cultivar carries WBR-1, but it also has additional resistance which is only expressed at the adult plant stage of growth.

The WBR-2 cultivars Fundin, Hobbit and Norman reacted similarly to the two isolates, but cvs Sappo (WBR-3) and Halberd (WBR-4) were both more susceptible to WBRS-86-9 which carries the corresponding virulence genes, not present in isolate WBRS-86-11. Cv. Wembley which gave a similar pattern of response as cvs Sappo and Halberd in the seedling tests was also more heavily infected with isolate WBRS-86-9 suggesting that it too carries either WBR-3 or WBR-4.

Other cvs more susceptible to isolate WBRS-86-9 in field tests were Brock, Tonic, Minaret, Alexandria, Galahad and Brimstone. Seedling tests results, however, show these cultivars not to possess either WBR-3 or WBR-4.

The resistance of the winter wheat cvs Moulin, CWW 36/5/40, Hornet, Mission, Parade and Rendezvous was effective against both isolates, as was that of the spring cvs Cub, Jerico, Axona and Dollar.

FUNGICIDE INSENSITIVITY

Fiona Boyle, J Gilmour and J H Lennard

In October 1987 an investigation of fungicide insensitivity in brown rust of wheat began at the East of Scotland College of Agriculture, funded by the Home-Grown Cereals Authority. The main aims are to establish current levels of sensitivity to the major fungicides used to control brown rust and to determine whether any changes have taken place since the early years of the brown rust survey. Samples collected for the UKCPVS and in the ADAS Wheat Survey will be screened for virulence at Aberystwyth and then tested for fungicide sensitivity at Edinburgh. Preliminary results with a small number of isolates indicate that there are differences among contemporary isolates in responses to a representative azole fungicide.

Table 3. Reactions+ of winter and spring* wheat cultivars to specific isolates of Puccinia recondita in field isolation nurseries in 1987

Cultivar	WBR factor	Isolate WBRS-86-9 (WBV 2,3,4,6,9)	WBRS-86-11 (WBV 1,2,6)
Clement	1	3	35
Fortress		2	28
Apollo		2	22
Rocket		1	21
Slejpner	1+?	0	0
Hornet		0	8MR
Aquila		0.1	23
Fundin	2	24MS	20
Hobbit		23	19MS
Norman		18	15
Sappo*	3	24	7
Halberd*	4	18	4
Huntsman	5	26	34
Gamin	6	16	18
Sabre	7	Trace	Trace
Sterna		0	0
Ranger	8	0.1R	0.5MS
Kinsman	8?	0.3R	1MR
Avalon	9	21	2
Moulin		1MS	0.5
Mandate		0	4MR
Dollar*		0	0.1
Jerico*		0	0
Axona*		0	0
Cub*		2	1
Mission		0.5MS	3MS
Parade		6MR	1
Rendezvous		7MR	0.5MR
Brimstone		15MS	1
Wembley*		12MS	2
Alexandria*		10	3
Minaret*		14	4
Tonic*		15	6
Fenman		17	15
Mercia		18	3
Galahad		21	8
Brock		28	9MS
Longbow		19	25
CWW 3547/1		23	26

+Mean of 3 replicates, 3 assessment dates (winter cvs)
" " " " , 2 assessment dates (spring cvs)

MILDEW OF BARLEY

M S Wolfe, Susan E Slater and P N Minchin

Institute of Plant Science Research (Cambridge Laboratory)

Pathogenicity for several resistance genes increased simultaneously in 1987 following the gradual replacement of cv. Triumph by new cultivars with various combinations of previously exposed resistance genes. Pathogenicity for cultivars with the newly exposed resistance from cv. Rupee also increased, but there was no confirmed evidence of any pathogen response to the mlo resistance in cv. Atem.

The occurrence in 1986 of pathogen phenotypes in Scotland with combined reduction in sensitivity to the three major fungicide groups was noted again in the same area in 1987.

Identification of resistance phenotypes

There were no new resistance phenotypes or combinations identified in 1987. Among the newly introduced winter barleys, several had the resistance from W. 41/145 alone (cv. Finesse) or combined with the W. 37/136 resistance (cv. Masto) or Mlg (cvs. Mimosa, Vixen). Cvs. Frolic and Kira probably have Mlg alone, while cv. Waveney has Mla12 alone and cv. Torrent has a combination of several genes including Mlg, Mla6 and the resistance from W. 41/145. The spring variety Joline has MlLa combined with Mlk and Mla7.

There was anecdotal evidence of a minor increase in infection on crops of cv. Atem, but this was not confirmed in laboratory tests. It is possible that initial adaptation to the mlo resistance interacts strongly with environmental conditions.

Pathogen population structure

Table 1 lists the principal differential cultivars used in the survey.

Table 1. Principal differential cultivars

BMR gp	Cultivar	BMR gp	Cultivar	BMR gp	Cultivar
0	Gld. Promise	6a (Mlk)	H. 1063	10a(Mla13)	Digger
1a	W. 37/136	6b (Mla7)	Porter	4,6b	Doublet
1b	W. 41/145	6ab	Ark Royal	4,6ab	Klaxon
2 (Mlg+)	Julia	6bc(Mla7,Ab)	Triumph	4,7	Vista
3 (Mla6)	Midas	7 (Mal)	Tyra	4,8	Kym
4 (MlLa)	Lofa	8 (Mla9)	Simon	5,6c	Natasha
5 (Mla12)	Hassan	9 (mlo)	Apex	5,10b(MlRu2)	Sherpa

Changes in frequency of the major pathogenicity characters in recent years are shown in Table 2, based solely on data from indirect tests of isolates from winter barleys lacking known major resistance genes. The European distribution of these characters is given elsewhere (Wolfe & Limpert, 1987).

Table 2. Changes in frequency of the major pathogenicity characters determined from apparently non-selective cultivars of winter barley

	BMV character											
Year	1b	2	3	4	5	6a	6b	6ab	6bc	7	8	10a
1978	-	68	34	7	28	51	-	35	0	0	0	-
1979	-	39	20	13	16	44	-	34	0	0	0	-
1980	-	61	27	16	21	-	-	38	2	5	0	-
1981	-	44	31	45	23	-	-	7	4	1	0	-
1982	-	48	45	31	41	-	-	18	4	1	0	-
1983	-	68	43	36	42	-	-	29	37	3	0	-
1984	56	47	51	15	13	-	-	52	52	1	1	-
1985	45	45	43	18	21	49	42	-	47	-	2	-
1986	26	28	23	8	24	26	23	-	24	1	2	0
1987	28	37	16	19	25	29	42	-	18	4	14	0

From Table 2 there was a closely correlated decline in BMV 3 and 6bc (pathogenicity for cvs Midas and Triumph). From other data, however, it is clear that these two characters became dissociated during the decline; most isolates pathogenic on cv. Triumph now lack pathogenicity for cv. Midas. RFLP analysis by J K M Brown of the previously common isolates pathogenic on both cvs. Midas and Triumph showed that they were closely similar. Thus the major increase of mildew on cv. Triumph was probably caused by only one or a few clones. The changes observed in 1987 were presumably due to replacement of these clones by others with wider pathogenicity and greater fitness, shown by the higher frequency of BMV 4, 6b, 7 and 8, all due to the increased cultivation of new cultivars with combined resistance genes, noted last year and below.

Winter barley cultivars with known resistance genes selected sub-populations of the pathogen which were considerably different from the general population on winter barleys (Table 3).

Table 3. Contrasting pathogen populations on non-selective (BMR1b) and selective winter barley cultivars

	BMV character								
BMR source	4	5	6a	6b	6bc	8	10a	4,6ab	5,6c
1b	19	34	22	33	19	5	0	9	34
5	20	94	2	3	0	3	0	3	13
6b	4	5	70	56	57	0	0	1	12
10a	0	52	60	90	63	55	55	0	4

Table 3 illustrates the persistence of the negative interaction of BMV 4 and 5 with BMV 6 on the selective cultivars. The high values of BMV 5 and 6 in the population from BMR 10a are clearly due to mixing rather than recombination because of the low values for the recombinant BMV 5,6c in the same population. The Table also shows a surprisingly high frequency of BMV 8 on BMR 10a; BMV 8 now appears commonly on a range of new resistant cultivars for which it is not needed. This may be due to primary selection of BMV 4,8 on cv. Kym with subsequent selection of the combination BMV 4,6,8 on new cultivars (see Table 6).

The range of pathogenicity characters in a bulk population of the pathogen from cv. Igri (BMR 1b) was compared with those of nine single colony isolates obtained from the same field (Table 4).

Table 4. Comparison of pathogenicity of a bulk population of the pathogen with nine single colony (SC) isolates

		BMV character									
	G*	2	3	4	5	6a	6b	6bc	4,6b	4,6ab	5,6c
SC1	77	30	68	25	0	0	19	10	0	0	0
2	7	0	89	16	0	0	0	0	0	0	10
3	54	37	61	35	8	0	8	0	0	9	10
4	106	36	57	35	16	0	0	0	0	0	27
5	107	9	35	13	7	0	12	0	0	0	24
6	80	12	3	7	19	35	50	0	35	34	21
7	127	37	0	18	30	61	137	23	13	17	67
8	266	147	124	84	8	0	64	0	10	2	0
9	153	39	93	0	51	0	0	0	0	0	24
mean	109	39	59	26	15	11	32	4	6	7	20
bulk	61	27	24	3	8	32	49	21	0	7	18

*G = cv. Goldfoil (Mlg alone)

Although cv. Julia has long been used as the representative cultivar for Mlg, it was known to possess a second, unidentified, quantitative resistance; cv. Goldfoil, on the other hand, carries Mlg alone. The difference between the two cultivars is evident from Table 4 in which SCs 1,3,4,7,8 and 9 probably all possess pathogenicity against both cultivars, whereas SCs 5 and 6 are pathogenic against Mlg but not against the second resistance in cv. Julia. Isolate 2 is non-pathogenic on both cultivars.

The majority of isolates in Table 4 (SCs 1 - 5 and 9) are remarkably simple. They also show again the negative correlation between BMV 4 and 5 on the one hand, and BMV 6 on the other. However, SC 8, which has BMV 4 and 6b combined, suggests that the negative correlation could stem from the relationship between BMV 4 and BMV 6a.

The values for the mean of the SCs differ from those of the bulk, apparently because the bulk contains a higher representation of the BMV 6 characters. It is not known which set of values represents more accurately the structure of the whole population.

From tests made with isolates obtained from different parts of England and Scotland in the WIST, there were no clear patterns of geographical distribution. The data have been amalgamated therefore to provide more detail of the changes between 1986 and 1987 than is available from Table 2 (Table 5).

Table 5. Population changes on winter (WB) and spring barley (SB) from 1986 to 1987

	1b	2	3	4	5	6a	6b	6bc	7	8	4,6b	4,6ab	5,6c
1986													
WB	26	28	23	8	24	26	23	24	1	2	0	0	0
SB	28	40	31	15	24	20	37	28	5	5	3	6	10
1987													
WB	28	37	16	19	25	29	42	18	4	14	10	19	20
SB	55	27	25	20	23	22	32	26	12	6	2	6	21

From Table 5, there were increases in several single and combined characters which reflect the increased cultivation of new cultivars with combined resistance genes. The changes observed in pathogen populations on individual spring barley cultivars are shown in more detail in Table 6.

Table 6. Population structure on barley cvs in 1986 and 1987

Cv./Yr.		3	4	5	6a	6b	6bc	7	8	4,6	4,7	4,8	5,6c
Trumph	86	21	2	8	52	41	50	0	0	0	0	0	10
6bc	87	6	1	3	52	45	46	0	0	1	0	0	54
Db/Kx*	86	8	33	41	70	62	3	0	27	49	0	24	8
4,6	87	18	45	37	46	35	3	2	28	56	6	36	12
Cameo	86	27	38	30	90	51	1	0	69	35	0	79	2
4,8	87	14	62	42	58	45	0	1	63	34	2	83	5
Regtta	86	16	32	12	63	37	0	106	11	11	106	18	1
4,6a,7	87	29	37	18	62	56	9	74	39	41	95	58	16
Natsh*	86	8	5	59	14	45	35	1	0	1	0	0	58
5,6c	87	11	13	42	33	47	34	3	1	3	1	3	79

* Db/Kx = mean of cvs. Doublet and Klaxon; Natsh = mean of cvs. Blenheim, Corniche and Natasha.

From Table 6, the population on cv. Triumph changed through the decline in BMV 3 and the increase in BMV 5,6c (cv. Natasha). As reported last year, recombinant cultivars selected for an increase in recombinant pathogen phenotypes. All of the recombinant cultivars that include BMR 4 selected for pathogen phenotypes that include BMV 4, 6 and 8. The population on cv. Regatta appears to be particularly dangerous since it may be pathogenic on many cultivars, though not on cv. Triumph and the BMR 5,6c cultivars.

Pathogen response to fungicides

From direct trapping in the WIST there was some evidence of a slight increase in sensitivity to azoles both in East Anglia and in England and Scotland generally (Tables 7, 8; see also the wheat mildew report).

Table 7. Changes with time of the relative frequencies of colony counts on barley seedlings treated with different amounts of triadimenol (E. Anglia)

Rate (g a.i. kg^{-1})	'81	'82	'83	'84	'85	'86	'87
0.025	23	51	83	85	64	52	68
0.075	-	27	54	54	70	62	-
0.125	-	-	-	24	43	45	76
0.250	-	-	-	-	-	74	61
0.375	-	-	-	-	-	44	30

The data in Table 7 are averages for the whole season, whereas those in Table 8 apply to June only.

Table 8. Geographical distribution of relative colony counts on seedlings treated with two rates of triadimenol (g a.i. kg^{-1})

Region	0.125				0.375	
	'84	'85	'86	'87	'86	'87
E. Anglia	24	43	45	32	44	17
E. Mids.	80	60	62	64	-	9
N. Engl.	35	27	53	16	24	14
Lothians	22	17	59	37	24	6
E. Scotl.	16	28	46	41	16	21
N. Scotl.	12	11	71	35	39	28
means	32	31	56	38	29	16

On average, the increase in sensitivity at the higher treatment appeared to be greater than at the lower treatment suggesting a decrease in frequency of the most insensitive but not of the intermediate forms. The greater sensitivity to azoles was also reflected in indirect tests, but is almost certainly too small to allow an improvement in performance of the azoles against barley mildew. The change was probably due to a general decrease in the use of azoles for mildew control combined with a switch to greater use of morpholines. RFLP analysis by J K M Brown indicated that the different levels of azole insensitivity are simply inherited. However, unlike the monomorphic development of pathogenicity on cv. Triumph, these characters probably evolved many times in different genetic backgrounds.

As with triadimenol, sensitivity to ethirimol also increased from 1986 to 1987; the lowest level remained in the east of Scotland (Table 9). In the East Anglia survey, it was clear that insensitivity to ethirimol reached a peak relatively early in the season (April/May), which is consistent with the use of ethirimol only in seed dressing formulations.

Although sensitivity to tridemorph also appeared to increase from 1986 to 1987 in northern England and the Lothians, there was a shift to increased insensitivity in eastern, and possibly northern Scotland (Table 9). These changes towards increased insensitivity to the morpholines in the far north were consistent with the data obtained from the previous two years suggesting a first response to these fungicides in this area (see UK CPVS Report for 1986). They were confirmed by indirect tests of the isolates obtained in the WIST.

Table 9. Geographical distribution of insensitivity to ethirimol and the morpholines in barley mildew (rates as proportion of field rate)

	ethirml(1/15)		tridmrph(1/20)		fenprop(1/100)	
	'86	'87	'86	'87	'86	'87
E. Angl.	-	11	-	27	-	11
E. Mids.	-	23	-	23	-	23
N. Engl.	31	15	61	4	0	0
Lothians	45	34	50	7	3	6
E. Scotl.	78	63	48	86	9	55
N. Scotl.	46	27	96	47	2	22

During the season, the peak for morpholine insensitivity was reached at the end of June, much later than for ethirimol in barley mildew, which is consistent with the use of morpholines only as foliar sprays.

From WIST catches in the same area in 1986 we were able to confirm the occurrence of pathogen genotypes with different degrees of combined insensitivity to triazoles, ethirimol and morpholines. Single colony isolates from these collections were tested during 1987 to confirm that the original isolates did indeed contain recombinants and were not simple mixtures (Table 10).

Table 10. Fungicide tests with single colony isolates obtained from Scotland in 1986

	Fungicide and rate relative to commercial application							
Source	Triad. 1:15	Triad. 1:3	Triad. 1:1	Ethir. 1:4	Frrx. 1:15	Trdph. 1:20	Fenpm. 1:100	Fenpd. 1:50
Lothians								
1	71	24	2	47	38	24	56	46
2	93	9	0	61	11	18	54	87
3	91	29	11	13	31	32	33	61
4	51	6	0	45	24	6	21	52
5	61	1	0	28	14	0	46	73
N. Sctlnd								
1	127	25	8	30	15	7	90	98
2	76	43	1	22	26	0	46	58
3	116	43	2	21	14	10	14	67
Controls								
min.	0	0	0	0	0	0	0	0
max.	78	84	70	20	4	0	0	0

From Table 10, all isolates could be classified as only intermediate in insensitivity to azoles, but they all showed some response to the three major groups of fungicides. Such recombinants have emerged despite the fact that the major fungicides have been used alone or, more recently, in mixtures containing only two of the possible three pairs of compounds; a mixture of all three has not been developed.

The use of fungicide mixtures following exposure of the materials singly to the pathogen population parallels the effect of using recombinant host cultivars, noted above and in the last annual report. It is not surprising therefore to find such potentially dangerous recombinants occurring but it is impossible to predict their likely importance in the field.

REFERENCE

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MILDEW OF BARLEY IN NORTHERN IRELAND

P.C. MERCER

Plant Pathology Research Division, Department of Agriculture, Northern Ireland

Weather conditions in 1987 were somewhat kinder to mildew than in the previous year and a total of 24 isolates was obtained, the bulk in spring barley. Table 1 shows the cultures used for examining the various virulences.

TABLE 1 Test cultivars for detection of virulence groups

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

Because of the popularity of Klaxon and Atem these two cultivars were added to the 1987 list. Table 2 shows the values for the mean pathogenicity of the isolates. Table 3 shows the values for non-corresponding pathogenicity for the past six years. The main features of 1987 were of figures greatly lower than 1986 and more akin to those of 1985. Figures for 1986 may not have been particularly reliable as only a small number of isolates could be gathered. However, taking this into account the most obvious differences in 1987 were the drop in BMV3, BMV5 and BMV3 + 4 (although not BMV4). The drop in BMV3 corresponds to a similar one in England (Wolfe, Slater and Minchin, 1987 and this report), where there was also a drop in 6b + c. It is not clear how significant the apparent drop in 6b + c in Northern Ireland was, but its frequency does certainly not appear to be increasing. Relatively high levels of 4 + 6a + b reflect the generally mildewed-nature of many Klaxon crops. Atem crops were still clean but there was a low level of isolation of mildew virulent on BMR4 + 9. From a survey the most popular cultivars in 1987 were Klaxon 36%; Delta 27%; and Regatta, Goldmarker and Atem (9% each).

TABLE 2 Mean pathogenicity of bulk isolates in 1987 on test range of cultivars

			BMV Characters													
BMR group	Isolate source	No	2	3	4	5	6a + b	6b + c	7	8	3 + 4	4 + 5	4 + 6a	4 + 6a + b	4 + 9
1b	Igri	1	109	64	105	12	11	39	17	2	9	86	10	0	8
1b	Plaisant	1	53	36	93	38	7	49	38	4	0	74	133	62	8
6a + b ?	Escort	1	90	17	47	35	98	22	0	22	18	60	88	20	2
6b + c	Triumph	3	79	37	40	50	53	92	2	7	13	36	40	18	1
7	Delta	3	92	27	69	46	46	19	60	42	5	78	23	23	6
2 + 4	Golf	2	76	16	32	20	52	78	43	23	18	33	56	29	0
3 + 4	Goldmarker	3	97	11	79	26	39	36	76	10	1	52	16	29	11
4 + 6a + b	Joline	1	45	1	54	20	59	36	15	11	11	56	33	17	1
4 + 6a + b	Klaxon	4	100	33	77	24	68	18	26	52	16	62	42	33	2
4 + 6a + 7	Regatta	5	102	23	79	29	34	32	64	9	10	77	38	45	7

TABLE 3 Non-corresponding pathogenicity values in Northern Ireland from 1983-1987

	BMV Characters									
Year	2	3	4	5	6a + b	6b + c	3 + 4	4 + 5	4 + 6a + b	4 + 9
1983	59	53	59	37	16	22	45	32	-	-
1984	48	45	42	40	17	24	29	38	-	-
1985	65	54	60	69	31	37	35	34	-	-
1986	140	68	143	84	53	59	35	61	-	-
1987	92	28	63	31	39	33	12	61	30	5

In 1987 tests were also made of insensitivity to triadimenol/fuberidazole seed dressing (Baytan). Seeds were treated with full-rate as well as 1/3 and 1/15 rates. Results are shown in Table 4. Rather surprisingly there was quite a high level of colonisation at all three rates. In fact there seemed to be very little differences between the rates. Delta appeared relatively more colonised than the other cultivars.

TABLE 4 Comparison of colony counts with three rates of Baytan seed-dressing relative to those on untreated seedlings.

Cultivar from which isolated	Full rate	1/3 rate	1/15 rate
Regatta	22	25	70
Klaxon	27	17	37
Delta	63	84	62
Triumph	54	18	26
Goldmarker	44	19	37
Golf	33	25	57
Mean	41	31	48

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YELLOW RUST OF BARLEY

R A Bayles, M H Meadway and P L Stigwood

National Institute of Agricultural Botany, Cambridge

Twelve samples were received during 1987, nine samples being successfully cultured. All isolates possessed BYV 1 and BYV 2, but only two were virulent on the BYR 3 differential Triumph.

INTRODUCTION

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

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

BYR Factor	Type*	Differential Cultivars	BYV detected
BYR 1	0	Astrix, Atem	1960
BYR 2	0	Bigo Varunda	)1972-1975
	S	Mazurka	)
BYR 3	?S	Triumph	1983

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

METHODS

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

Seedling tests with 1987 isolates

Twelve samples were received in 1987. Of the nine successfully cultured samples, one was received from Lincolnshire, and eight from Northumberland.

The increase in samples compared with 1985(1) and 1986(0) reflects the generally cooler and wetter conditions throughout the season.

RESULTS

Virulence frequencies for 1976-1987 are shown in table 2.

Table 2 Virulence factor frequency (%)

BYV Factor	Common name	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987
BYV 1	Astrix virulence	100	100	98	-	100	100	100	100	100	-	-	100
BYV 2	Bigo virulence	0	18	32	-	54	81	96	87	100	-	-	100
BYV 3 †	Triumph virulence	-	-	-	-	-	-	-	17	86	-	-	22
Number of isolates tested		17	27	44	1	56	52	25	30	7	1	0	9

† Not included in tests before 1983.

Only two isolates were virulent on Triumph, indicating decreased virulence for BYR 3 in 1987. This conclusion should be treated with caution because of the small number of isolates involved.

REFERENCES

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BROWN RUST OF BARLEY

E.R.L. Jones

Institute for Grassland and Animal Production,
Welsh Plant Breeding Station, Aberystwyth

Isolates of *Puccinia hordei* Otth. were tested from 97 of the 192 samples received in 1987. These included 26 isolates received from the HGCA-funded MAFF cereal survey, to be further screened at the E.S.C.A. for fungicide insensitivity. No new virulences or virulence combinations were detected, the widely virulent octal race 1673 being predominant. Cultivar Corniche displayed a pattern of response similar to cv. Triumph in seedling tests, but is resistant to isolates possessing the Triumph virulence (BRV-10) at the adult plant stage, suggesting that it has additional adult plant resistance. In field isolation nurseries, the winter barley cv. Opera showed low levels of infection to isolates 1673 and 677. Comparisons of reactions of spring cultivars inoculated with three different isolates in the field allowed circumstantial identification of specific resistances within cultivars.

GLASSHOUSE SEEDLING TESTS WITH 1987 ISOLATES

One hundred and ninety-two samples of barley brown rust were received. This number included 26 samples sent from the MAFF cereal survey, specifically for fungicide insensitivity screening at ESCA (Dr J. Gilmour, HGCA funded project). The samples originated from a wide range of winter (164) and spring (27) cultivars. The 97 isolates of *P.hordei* cultured were tested on the standard set of 10 differential cultivars (Table 1). Cultivar Corniche was also tested against the isolates as it has shown high levels of resistance in the previous years' isolation nurseries.

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

Cultivar	BBR factor	Gene symbol	Ranking for octal notation
Sudan	1	Pa	1
Peruvian	2	Pa_2	2
Ribari	3	Pa_3	3
Gold	4	Pa_4	4
Quinn	5	Pa_5	5
Bolivia	6	Pa_6	6
Cebada Capa	7	Pa_7	7
Egypt 4	8	Pa_8	8
C.I. 1243	9	Pa_9	9
Triumph	10	$Pa_?$	10

Results

The virulence combinations identified and their frequencies are given in Table 2. No new virulences or virulence combinations were identified from the isolates tested in 1987. The spring barley cv. Corniche displayed a pattern of response similar to that of cv. Triumph to all of the isolates. This suggests that it possesses the same resistance gene(s) as cv. Triumph, although it also appears to have additional resistance which is expressed at the adult plant stage of growth (see below).

Table 2. Virulence combinations (races) identified from 1987 isolates

Number of isolates (frequency)	Octal designation	BRV factors
54 (0.56)	1673	1,2,4,5,6,8,9,10
30 (0.31)	1653	1,2,4,6,8,9,10
12 (0.12)	673	1,2,4,5,6,8,9
1 (0.1)	1657	1,2,3,4,6,8,9,10

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Two isolation nurseries comprising 28 winter and 20 spring barley cultivars were sown in the autumn and spring of 1986-87. A third nursery was sown with spring barleys only in the spring of 1987. The nurseries were inoculated with one of the three following isolates of *P.hordei*.

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

The less widely virulent octal race 11 was introduced into the nursery sown with spring cultivars only, as previous results had indicated that certain winter barley cultivars are resistant to this race: information on current spring cultivars is thus of interest.

Results

High levels of infection developed within the nurseries inoculated with isolates octal 11 and octal 1673, whilst lower but still reasonable levels were achieved within the nursery inoculated with octal 677 (Tables 3 and 4). The winter barley cultivars (Table 3) again displayed a range of quantitative responses to isolates 1673 and 677 from the highly susceptible cvs Kaskade and Torrent (ca. 20%) to the low level of infection, of a mixed reaction type (3% MS) of cv. Opera. These cultivar differences were generally of a non-specific nature with cultivar rankings between isolates remaining constant. One exception to this was cv. Masto which was highly susceptible to race 1673 (mean of 18% infection) but resistant to race 677 which suggests that it may carry BRR-10 derived from cv. Triumph.

Levels of infection in the race 677 nursery were generally lower which makes interpretation rather difficult and cultivar classification should be viewed in this light. However, the following groupings also rely on previous years' results which strengthens the interpretations.

Group I cultivars are not known to carry any resistance. Group II included those cultivars with cv. Triumph resistance (BRR-10), which is effective against octal race 11 (BRV-1,4) and octal race 677 (BRV-1,2,3,4,5,6,8,9), but not octal race 1673 which carries BRV-10. This includes cvs Natasha, Doublet, Prisma and also Blenheim, Klaxon and Regatta. Cultivars Vista, Joline and Armelle, although more resistant to octal race 1673, were also placed in this group.

Cultivars Atem, Kym, Cameo, Digger and Ilka were placed in Group III with cv. Vada which has a non-specific resistance. These cultivars were susceptible to all three isolates tested but did not show the same high levels of infection of cvs Midas and Golden Promise. Cultivar Simon (BRR-3) was susceptible only to octal race 677 which carries the corresponding virulence factor (BRV-3) and is placed on its own in Group IV. As in previous years cv. Corniche showed low levels of infection to all isolates, but as stated earlier is susceptible to Triumph virulent (BRV-10) isolates at the seedling stage.

FUNGICIDE INSENSITIVITY

Fiona Boyle, J Gilmour and J H Lennard

In October 1987 an investigation of fungicide insensitivity in brown rust of barley began at the East of Scotland College of Agriculture, funded by the Home-Grown Cereals Authority. The main aims are to establish current levels of sensitivity to the major fungicides used to control brown rust and to determine whether any changes have taken place since the early years of the brown rust survey. Samples collected for the UKCPVS and in the ADAS Barley Survey will be screened for virulence at Aberystwyth and then tested for fungicide sensitivity at Edinburgh. Preliminary results from a small number of isolates indicate that contemporary and historic isolates differ in their response to a representative azole fungicide.

Table 3. Reactions of Winter Barley Cultivars to Specific Isolates of P.hordei Otth. in field isolation nurseries in 1987

Winter cultivar (NIAB rating)	Isolates: Octal race 1673 BRV-1,2,4,5,6,8,9,10	Octal race 677 BRV-1,2,3,4,5,6,8,9
Kaskade (5)	23*	12
Torrent	21	18
Mimosa	19	15
Masto	18	6
Plaisant	17	15
Magie (5)	17	12
Gerbel (5)	17	10
Waveney	15	14
Kira	15	12
Marinka (5)	14	8
Concert (4)	14	5
Pirate (6)	13	11
Mallard	13	7
Otter (5)	11	15
Frolic	11	7
Eclat	11	3 MS
Tipper (6)	10	7
Panda (7)	10	7
Vixen	8 MS	9 MS
Nevada (5)	8	4 MS
Igri (5)	8	5
Pipkin (4)	7	11
Fallon	7	5 MS
Jennifer	7	4
Sonate (6)	7 MS	10 MS
Finesse	6	7
Halcyon (6)	5	6
Opera (6)	3 MS	3 MS

*% infection for mean of 4 replicates at 3 assessment dates
All reaction types susceptible unless stated. MS = Mixed susceptible

Table 4. Reactions of spring barley cultivars to specific isolates of P.hordei Otth. in field isolation nurseries in 1987

Spring cultivar (NIAB rating)	Isolates: Octal race 1673 BRV-1,2,4,5,6,8,9,10	Octal race 677 BRV-1,2,3,4,5,6,8,9	Octal race 11 BRV-1,4
Group I (BRR-0)			
Golden Promise	27*	18	31
Midas	27	18	27
Group II (BRR-10)			
Triumph (5)	12	3 MS	Trace
Prisma	17	5 MS	0.1
Doublet (5)	12	4 MS	0.2 MS
Natasha (5)	7	4 MS	Trace
Blenheim (4)	20	5	0.2 MS
Klaxon (6)	11	6	1 MR
Regatta (6)	8	5	2 MR
Joline (8)	3	6	0.5 MR
Vista	5 MS	5 MS	0.2 MR
Armelle	3 MS	7	0.2 MR
Group III (BRR-V?)			
Vada	4 MS	4 MS	12
Atem (4)	19	8	20
Kym (6)	15	9 MS	11
Cameo (5)	13	8 MS	16
Digger (6)	13	6	12
Ilka	5	4 MS	9
Group IV (BRR-3)			
Simon	0	8	Trace
Group V (BRR-10+?)			
Corniche (8)	2 MS	0.5 MS	0.2 R

*% infection for mean of 4 replicates at 3 assessment dates
All reaction types susceptible unless stated
MS = Mixed susceptible; MR = Mixed resistant; R = Resistant

RHYNCHOSPORIUM OF BARLEY

E.R.L. Jones & B.C. Clifford

Institute for Grassland and Animal Production,
Welsh Plant Breeding Station, Aberystwyth

Sixty-one isolates of *Rhynchosporium secalis* were tested on seedlings in 1987. The frequency of virulence to cv. Pirate (BRR-7) was 0.46, an increase of ca 100% over the two previous years. The resistance of the spring barley cv. Digger, remains effective to all isolates at the seedling stage. Virulence of isolate Rs-85-50 (octal race 77) to the winter barley cv. Pipkin (BRR-5) and the spring barley cvs Corgi (BRR-5), La Mesita (BRR-5) and Osiris (BRR-6) was confirmed in field isolation nurseries. Cultivar Armelle (BRR-1) and Joline (BRR-?) were resistant to isolate octal race 0 which does not carry the corresponding virulence factors.

SEEDLING TESTS WITH 1987 ISOLATES

A total of 90 samples of barley leaf blotch was received. The infected leaf samples came from a wide range of 59 winter and 28 spring barley cultivars, the geographic origins of which are given in Table 1. Three of the samples were of unknown cultivar origin.

Table 1. Geographic origin of Rhynchosporium samples received in 1987

Geographic origin	Number of samples
Wales	26
Scotland	11
Eire	3
England (ADAS Region)	
East	35
West-central	11
South-west	3
East-central	1
Total	90

Sixty-one isolates were successfully cultured and tested on the current set of differential cultivars and additional winter and spring cultivars. Test cultivars and their resistance factors are given in Table 2.

Table 2. Differential test cultivars for Rhynchosporium secalis

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

Results

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

Table 3. Virulence factor combinations identified from the 1987 survey

No. of isolates	Differential cultivars in fixed linear order							Octal virulence designation
	Pirate	Osiris	La Mesita	Igri	Athene	Astrix	Armelle	
18	0	0	0	1	1	0	0	14
15	0	0	0	0	0	0	0	0
10	1	0	0	0	1	0	0	104
10	1	0	0	1	1	1	1	117
8	1	0	0	1	1	0	0	114
Virulence frequency	0.46	0	0	0.59	0.75	0.16	0.16	

All virulence combinations had been identified in previous years. Virulence to cv. Pirate was found at a frequency of 0.46, a considerable increase compared with 0.22 in 1986, and 0.20 in 1985. The spring barley cv. Digger which was included in the seedling tests because of its high level of resistance in the 1986 isolation nurseries was resistant to all isolates tested, as were the differential cvs Osiris and Le Mesita. The winter barley cvs Gerbel and Hoppel were relatively resistant to all the isolates.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Two nurseries comprising 31 winter and 22 spring cultivars were sown in the 1986-87 season using standard procedures. The nurseries were each inoculated with one of the following isolates.

Table 4. Isolates used in field tests in 1987

UK CPV Code Survey	Virulence characteristics	Octal designation
Rs-85-50	BRV-1,2,3,4,5,6	77
Rs-86-135	BRV-0	0

The nursery inoculated with isolate Rs-86-135 was grown alongside a Rhynchosporium disease screening nursery which was also infected with octal race 0.

Results

Very high levels of infection were achieved within the nursery inoculated with octal race 0, due to infection from the adjoining heavily infected screening nursery. The results for winter cultivars are summarised in Table 5 and for spring cultivars in Table 6. Quantitative differences were apparent between winter cultivars within individual nurseries reflecting differences in susceptibility of the cultivars.

Cultivar Pipkin (BRR-5) was the most highly infected cultivar in the nursery inoculated with octal race 77, which carries the corresponding virulence factor BRV-5. High levels of infection were also recorded on this cultivar in the nursery inoculated with isolate Rs-86-135, although this lacks BRV-5. This confirms the adult plant susceptibility of cv. Pipkin which is also a feature of cv. La Mesita from which cv. Pipkin derives its resistance (Clifford & Jones, 1982). Other winter cultivars which were relatively more susceptible to octal race 77 are Igri (BRR-4) and Jennifer, Vixen, Mallard, Frolic, Fallon and Nevada which were bred from Igri. Cultivar Tipper which is susceptible to race 77 at the seedling stage was also more highly infected within this nursery.

The spring cv. La Mesita (BRR-5) showed higher levels of infection within the nursery inoculated with Rs-85-50, as did cv. Corgi which carries the same resistance gene. Other spring cultivars to show specific resistance to isolate Rs-86-135 were cv. Armelle (BRR-1), Osiris (BRR-6) and Joline (BRR-?).

Cultivar Digger, which remains resistant in seedling tests, had 10% of its leaf area infected by octal race 0 in the corresponding nursery. A culture made from infected leaves of the cultivar failed to infect its own host in subsequent seedling tests. Cultivar Digger may therefore either display a similar effect to cv. La Mesita in becoming more susceptible on its upper leaves, or the sheer volume of inoculum within the nursery may have induced partial susceptibility.

FUNGICIDE INSENSITIVITY

The WPBS continued its contribution to a cooperative project between Ciba-Geigy and Long Ashton Research Station aimed at evaluating sensitivity of R.secalis to propiconazole and other EBI fungicides. These results are being anlysed and will be published elsewhere.

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Table 5. Percent infection* relative to Maris Otter of winter barley cultivars in Rhynchosporium isolation nurseries, 1987

Cultivar	Isolate Rs-85-50 BRV-1,2,3,4,5,6	Isolate Rs-86-135 BRV-0
Otter	100 (10)	100 (46)
Sonate	50	63
Kaskade	50	56
Kira	50	52
Pipkin	160	50
Eclat	50	46
Panda	35	43
Vixen	70	35
Magie	30	35
Athene	40	33
Mallard	50	30
Nevada	100	24
Frolic	50	24
Finesse	30	24
Gerbel	20	22
Fallon	60	20
Pirate	20	17
Astrix	40	15
Jennifer	60	11
Igri	60	11
Halcyon	30	11
Opera	30	11
Tipper	90	9
Mimosa	20	9
Concert	10	9
Masto	40	6
Hoppel	20	6
Plaisant	30	6
Marinka	10	6
Waveney	40	4
Torrent	30	4

*Mean of 3 scoring dates, 4 replicates
( ) actual % leaf area infected

Leaf area infected on cv. Otter inoculated with isolate Rs-86-135 on
1st scoring date = 40%
3rd scoring date = 60%

Table 6. Percent infection* relative to cv. Ilka of spring barley cultivars in Rhynchosporium isolation nurseries - 1987

Cultivar	Isolate Rs-85-50 BRV-1,2,3,4,5,6	Rs-86-135 BRV-0
Ilka	100 (41)	100 (58)
Natasha	44	100
Doublet	46	97
Blenheim	51	95
Prisma	76	95
Corniche	39	84
Golden Promise	29	76
Triumph	22	76
Cameo	41	71
Klaxon	22	64
Midas	37	62
Kym	27	62
Regatta	41	62
Vista	24	50
Proctor	15	46
Atem	39	45
Digger	1	17
La Mesita	32	14
Corgi	19	0
Armelle	17	0
Joline	15	0
Osiris	7	0

*Mean of 2 scoring dates, 4 replicates
( ) actual % leaf area infected

Leaf area infected on cv. Ilka inoculated with isolate Rs-86-35 on
1st scoring date = 36%
2nd scoring date = 80%

NET BLOTCH OF BARLEY

E.R.L. Jones & B.C. Clifford

Institute for Grassland and Animal Production,
Welsh Plant Breeding Station, Aberystwyth

Isolates carrying between 1 and 5 specific virulences in various combinations were identified from the 24 isolates of *Pyrenophera teres* Drechs. tested on seedlings. Within the spring differential cultivars virulence to C.I. 4795, was detected for the first time since 1982. All of the isolates lacked virulence to C.I. 6311, C.I. 1243 and C.I. 4979, a pattern of response last noted in 1983. The winter cv. Code 65 was again resistant to all isolates. The winter barley cv. Marinka, resistant in previous years' tests was susceptible to 19 isolates. Infection failed to develop within the isolation nurseries.

GLASSHOUSE SEEDLING TESTS WITH 1987 ISOLATES

Forty-nine samples of net blotch were received in 1987. Forty were from winter barley cultivars (19 of which were sampled from cv. Igri) and four from spring cultivars. Five were of unknown origin. The geographical origin of the samples was as follows:

Location		No. of samples
England (ADAS Region)	East	19
	West-Central	15
	South	4
	North	4
	South-west	3
	East-central	1
Wales		1
Unknown		2

The isolates of *Pyrenophora teres* Drechs. successfully cultured were inoculated onto seedlings of 13 differential cultivars plus 16 additional winter barley cultivars. Procedures used were those described previously (Clifford & Jones, 1981).

Results

Viable cultures were made from 24 of the samples. The frequencies of individual virulences corresponding to resistance factors in the 13 differential cultivars together with virulence frequencies over the period 1983-1986 are given in Table 1.

Table 1. Frequencies (%) corresponding to each differential cultivar (UK CPV Surveys 1983-1987)

Code number	Cultivar	1983	1984	1985	1986	1987	Mean
1	C.I. 5401	0	0	14*	0	0	3
2	C.I. 6311	0	22	21	39	0	16
3	C.I. 9820	0	0	56*	4	0	12
4	C.I. 739	24	33	33	61	20	34
5	C.I. 1243	0	44	42	57	0	29
6	C.I. 4795	0	0	0	0	10	2
7	C.I. 4502	0	0	0	0	0	0
8	C.I. 4979	0	44	33	50	0	25
9	Proctor	52	55	90	79	30	61
10	Code 65 (W)	19	0	7	0	0	5
11	C.I. 9518 (W)	90	100	90	96	90	93
12	Tenn. 61-119 (W)	19	44	33	57	60	43
13	C.I. 9214	9	0	0	0	0	2
No. of isolates tested		21	9	15	28	24	

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

The spring cultivars C.I. 5401, C.I. 9820, C.I. 4502, C.I. 9214 gave zero frequencies of corresponding virulences confirming the pattern of responses noted in previous years. Virulence to cvs C.I. 6311, C.I. 1243 and C.I. 4979 was also not detected, a trend previously noted in 1983. Cv. C.I. 4795 was susceptible to two isolates, the first time that virulence has been detected to this cultivar since 1982. The winter cv. Code 65 was again resistant to all the isolates tested.

Virulences occurred in various combinations in the different isolates (Table 2). The virulence combinations, designated according to the corresponding differential code numbers (Table 1) gave a range from the single virulence factor BNV-11 to the more complex and widely virulent BNV-4,6,9,11,12. Two isolates failed to give a fully compatible susceptible reaction on any of the 13 standard differential cultivars.

Table 2. Virulence combinations and their frequencies (1987 isolates)

Virulence combination BNV-	Number of isolates
11	9
11,12	5
9,11,12	4
4,9,11,12	2
4,6,9,11,12	2

The frequency of virulence to the additional 16 winter barleys included in the tests was high (Table 3). Cv. Igri, from which a large number of the samples was obtained, was susceptible to 22(92%) of the isolates. Cv. Marinka which was resistant to all isolates tested in 1985 and 1986 was susceptible to 19(80%) isolates in 1987. The dramatic increase in virulence on cv. Marinka is difficult to explain in that the cultivar occupied only about 5% of the hectarage in 1987 which was similar to the previous year.

The possibility of the test seed stock being non-authentic can be discounted because in that event, one would have expected a uniform response to all isolates i.e. susceptible. It would thus appear that the results are consistent with a significant change in virulence in the pathogen population.

Table 3. Frequencies (%) of virulences corresponding to each of the additional winter barley cultivars tested as seedlings against 1987 isolates

Cultivar	Frequency (%)
Kira	100
Calix	100
Plaisant	100
Mimosa	100
Igri	92
Carrera	92
Concert	86
Finesse	86
Melusine	86
Waveney	86
Marinka	80
Panda	75
Frolic	64
Gaulois	56
Torrent	46
Koala	40

FIELD ISOLATION NURSERIES

Twenty-eight winter and 17 spring cultivars were sown in each of two nurseries in 1986-1987, following standard procedures. The nurseries were inoculated with one or the other of the following isolates:

Survey code	Virulence combination
BNS-80-12 (net)	7,8,9,10,11,12
BNS-85-49 (spot)	1,3,5,9,11,12

Results

Repeated inoculation of the nurseries with spore suspensions of the isolates failed to produce infection within either nursery. This reflects the general difficulties that workers have with artificial field inoculation with P.teres. Planned modifications to our procedures to overcome these problems in 1988 include the use of glasshouse-infected transplants to initiate infection in spreader beds.

REFERENCES

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MILDEW OF OATS

E.R.L. Jones

Institute for Grassland and Animal Production,
Welsh Plant Breeding Station, Aberystwyth

A total of forty-one mildew samples were received, of which twenty-one were successfully cultured and tested. The trend observed in recent years continued in that the predominant virulence combination was the relatively complex OMV 1,2,3 (race 5) with 85% frequency, able to attack all commercial oat cultivars. The simpler race 3 (OMV 1,2) which is unable to attack cultivars with OMR 3 resistance such as Rollo declined in frequency in 1987. Virulence to *Avena barbata* (OMR 4) resistance was not detected.

SEEDLING TESTS WITH 1987 ISOLATES

Twenty-five of the 41 samples of *Erysiphe graminis avenae* received in 1987 were from spring cultivars. The remainder were from a wide range of winter oat cultivars with the exception of one sample of unknown origin. The 27 samples received from England were from the following ADAS regions: 14 from West Central, 7 from the North, 3 from East Central and 3 from the East. Seven samples were also received from Wales, 5 from Eire, 1 from Scotland and 1 of unknown origin. The 21 isolates which were successfully cultured were tested using methods described previously (Jones & Jones, 1984).

Results

Details of the mildew samples tested are given in Table 1, and the frequency of occurrence of the various virulences detected in 1987 compared with the previous three years, is shown in Table 2. The predominant virulence combination in 1987, as in the previous three years, was the relatively complex OMV 1,2,3 (race 5) with 85%. This widely virulent combination is able to attack cultivars in OMR Group 2 (e.g. Rhiannon, Cabana) and OMR Group 3 (e.g. Rollo, Avalanche, Panema) as well as the OMR 1 cultivars Pennal, Peniarth, Bulwark and Dula. The increased prevalence of this race in 1987 is therefore, probably due to the increased hectarage in recent years of cultivars with OMR 3 resistance like Rollo, Avalanche and Rhiannon.

Race 3 (OMV 1 + 2) was the only other virulence combination identified from the isolates tested in 1987. This simpler race, able to attack only cultivars with OMR 1 (Bulwark, Pennal, Dula) and OMR 2 (Rhiannon, Cabana), is declining in frequency compared with race 5 (OMV 1+2+3).

The simple races OMV 1 (race 2) and OMV 1,3 (race 4) were not detected in the 1987 samples.

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

Location	Cultivars	Virulences (OMV)
ENGLAND (West-central)		
Harper Adams, Salop	Peniarth, Image, Bulwark, Leanda, Commander, Major, Cabana, Avalanche, Keeper	1 + 2 + 3
ENGLAND (East-central)		
Headley Hall, North Yorkshire	Dula	1 + 2
ENGLAND (North)		
Cockle Park, Northumberland	Pennal, Dula, Lustre	1 + 2 1 + 2 + 3
WALES		
Trawsgoed, Dyfed	Commander, Major, Keeper Avalanche, Cabana, Dula, Rollo	1 + 2 + 3
EIRE		
Leixlip, Co. Kildare	Pennal	1 + 2 + 3

Table 2. Virulence group frequencies identified from samples received in 1987 compared with previous three years

Virulence Group	Virulence Race	Frequency (% total) 1984	1985	1986	1987	No. of isolates in 1987
OMV 1	2	0	0	0	0	0
OMV 1,2	3	32	37	31	15	3
OMV 1,3	4	2	0	0	0	0
OMV 1,2,3	5	64	46	63	85	18
OMV 1,2,4	6	0	4	0	0	0
OMV 1,2,3,4	7	2	13	6	0	0
No. of isolates tested		41	24	16	21	21

Virulence to the A.barbata (OMR 4) resistance was not detected, although several of the isolates gave 1-2 type pustules when inoculated onto the differential Cc 6490 (OMR-4). Cultivars carrying this resistance are not yet grown commercially within the UK.

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CROWN RUST OF OATS

E.R.L. Jones & B.C. Clifford

Institute for Grassland and Animal Production,
Welsh Plant Breeding Station, Aberystwyth

Only one sample of oat crown rust from a cultivar of unknown origin was received in 1987 from Wales. An isolate of *Puccinia coronata* was cultured from the leaf sample. Seedling tests on the 10 differential cultivars identified the isolate, CRS-87-1, as being race 251. This virulence combination is compatible with the differential cvs Appler, Bond and Saia and occurs commonly in the UK.

VARIETY DIVERSIFICATION SCHEMES FOR WINTER WHEAT AND WINTER AND SPRING BARLEY, 1988

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

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

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

The schemes currently available are for yellow rust and mildew of winter wheat and for mildew of winter and spring barley. The UKCPVS has also examined the possibility of including brown rust in the wheat scheme. With current varieties, diversification for brown rust is not effective, but the position will be reviewed regularly. Varieties with good resistance to brown rust are available and should be grown in areas where there is a high risk of the disease occurring. Further details of specific resistances to brown rust in wheat varieties are given in the paper 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 1988

Severe infections may result if yellow rust or mildew spread between varieties which are susceptible to the same races of the pathogens. This risk is reduced if varieties with high levels of resistance are grown. Disease spread can be limited further by sowing different varieties in neighbouring fields, provided that they are not susceptible to the same races of yellow rust or mildew. The Diversification Scheme should be used to choose winter wheat varieties to grow adjacent to each other.

Choosing varieties to grow together

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

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

DG 1A
Brock
Fenman
Mercia
Parade

DG 1E
Aquila

DG 1F
Fortress

DG 1H
Boxer
Mission

DG 1G
Apollo
Hornet
Mandate
Rocket

DG 1K
Rendezvous

DG 2H
Riband

DG 3B
Norman

DG 7G
Slejpner

DG 8B
Galahad

DG 9B
Avalon
Brigand

DG 9F
Rapier

DG 12B
Longbow

DG 13B
Brimstone

DG 14F
Soliel

Companion DGs

Chosen DG	1A	1E	1F	1G	1H	1K	2H	3B	7G	8B	9B	9F	12B	13B	14F
1A	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
1E	+	m	m	+	m	+	m	+	+	+	+	m	+	+	m
1F	+	m	m	m	m	m	m	m	m	m	m	m	m	m	m
1G	+	+	m	m	+	+	+	+	m	+	+	m	+	+	m
1H	+	m	m	+	m	m	m	+	+	+	+	m	+	+	m
1K	+	+	m	+	m	m	m	m	+	m	m	m	m	m	m
2H	+	m	m	+	m	m	ym	y	+	+	+	m	y	y	m
3B	+	+	m	+	+	m	y	ym	+	m	ym	ym	ym	ym	m
7G	+	+	m	m	+	+	+	+	ym	+	+	m	+	+	m
8B	+	+	m	+	+	m	+	m	+	ym	m	m	m	m	m
9B	+	+	m	+	+	m	+	ym	+	m	ym	ym	m	m	m
9F	+	m	m	m	m	m	m	ym	m	m	ym	ym	m	m	m
12B	+	+	m	+	+	m	y	ym	+	m	m	m	ym	m	m
13B	+	+	m	+	+	m	y	ym	+	m	m	m	m	ym	m
14F	+	m	m	m	m	m	m	m	m	m	m	m	m	m	ym

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN BARLEY 1988

Severe infections may result if mildew spreads between varieties which are susceptible to the same race of the pathogen. This risk is reduced if varieties with high levels of resistance are grown. Spread can be limited further by sowing different varieties in neighbouring fields provided that they are not susceptible to the same races of mildew. The Diversification Scheme should be used to choose a) winter or spring barley varieties to grow adjacent to each other and b) spring barley varieties to grow adjacent to winter barley.

Choosing varieties to grow together

1) Decide upon first-choice variety and locate its Diversification Group (DG).
   (W) = winter variety; (S) = spring variety
2) Find this DG number under 'Chosen DG' down left hand side of table.
3) Read across table to find the risk of mildew spread for each companion DG.
   + = low risk of spread of mildew
   m = high risk of spread of mildew

DG 0
Concert (W)
Fallon (W)
Finesse (W)
Frolic (W)
Gerbel (W)
Halcyon (W)
Igri (W)
Jennifer (W)
Kira (W)
Magie (W)
Mallard (W)
M. Otter (W)
Mimosa (W)
Nevada (W)
Panda (W)
Pirate (W)
Plaisant (W)
Torrent (W)
Vixen (W)
Corgi (S)
Golden Promise (S)

DG 1
Eclat (W)
Masto (W)
Sonate (W)
Camargue (S)

DG 2
Apex (S)
Atem (S)

DG 3
Golf (S)

DG 4
Pipkin (W)
Digger (S)
Ilka (S)
Sherpa (S)
Tyne (S)

DG 5
Kaskade (W)
Waveney (W)
Blenheim (S)
Corniche (S)
Heriot (S)
Kingpin (S)
Natasha (S)
Prisma (S)

DG 6
Marinka (W)
Triumph (S)

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

DG 8
Cameo (S)
Kym (S)
Tweed (S)

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

Chosen DG	DG 0	DG 1	DG 2	DG 3	DG 4	DG 5	DG 6	DG 7	DG 8	DG 9
DG0	m	m	m	m	m	m	m	m	m	m
DG1	m	+	+	+	+	+	+	+	+	+
DG2	m	+	m	+	+	+	+	+	+	+
DG3	m	+	+	m	+	m	+	+	m	m
DG4	m	+	+	+	m	+	+	+	+	+
DG5	m	+	+	m	+	m	m	+	+	m
DG6	m	+	+	+	+	m	m	+	+	m
DG7	m	+	+	+	+	+	+	m	+	+
DG8	m	+	+	m	+	+	+	+	m	m
DG9	m	+	+	m	+	m	m	+	m	m