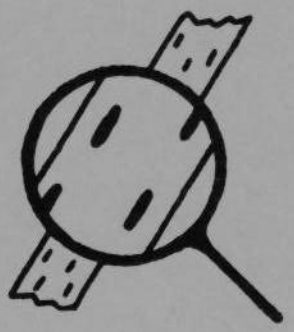
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1983 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

Chairman: Dr F J Moore, O.B.E.

Secretary: Dr R A Bayles, National Institute of Agricultural Botany,
Huntingdon Road, Cambridge, CB3 OLE

Tel: Cambridge (0223) 276381

1983 Annual Report

Published by the United Kingdom Cereal Pathogen Virulence Survey Committee

Cambridge, England

June 1984

Price £1

Printed by the National Institute of Agricultural Botany, Cambridge.

MEMBERS OF THE UK CEREAL PATHOGEN VIRULENCE SURVEY COMMITTEE, 1983-84

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Dr M S Wolfe	Plant Breeding Institute, Cambridge

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.

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 the Agricultural Development & Advisory Service booklet 'The use of fungicides on cereals'.

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 1983

Mildew of Wheat

All sampled populations displayed extensive variation for pathogenicity which was more readily detectable in direct differential tests than in tests of laboratory-maintained isolates. Insensitivity to low doses of the SI chemical triadimenol increased in eastern England but was influenced by several factors including the time of sampling. The negative association between this insensitivity and pathogenicity matching WMR 4, WMR 5+8+? and WMR 2+4+6 was confirmed.

Yellow Rust of Wheat

Virulence for the previously resistant cultivar Stetson (WYR 1,9) was detected in 23% of the isolates received in 1983. In adult plant tests, Stetson was very susceptible to an isolate possessing corresponding virulence. One isolate possessed combined virulence for the three adult plant resistances, WYR 12, WYR 13 and WYR 14.

Brown Rust of Wheat

Cultivars Virtue, Hustler, Rapier and Moulin were resistant to all isolates tested in field nurseries. Isolates were identified from the 1983 survey which overcame the temperature-sensitive (effective at 10°C) resistance of cvs. Virtue, Hustler and Rapier at the adult plant stage of growth in controlled environmental tests.

Mildew of Barley

There was a further, rapid increase in pathogenicity for BMR 6+Ab (cvs. Triumph, Tasman). There was also a further increase in insensitivity to triazole fungicides, at least in England. The latter change was associated with an increase in pathogenicity for BMR 3 (cvs. Midas, Carnival), apparently due to "hitchhiking" of the pathogenicity character with the fungicide insensitivity.

In Northern Ireland pathogenicity for BMV 6+Ab increased in 1983 while those for other virulence groups remained similar to previous seasons. Combined virulences for 3+4 and 4+5 appear to be much greater than in Great Britain.

Yellow Rust of Barley

Virulence for seedlings of the cultivar Triumph was detected in 17% of the isolates received in 1983. A number of isolates from winter barley crops in Scotland produced high levels of infection on adult plants of a range of winter barley cultivars.

Brown Rust of Barley

Virulence to cv. Triumph was detected from field crop samples. In tests of adult plants in field nurseries, inoculated with an isolate virulent on cvs. Triumph and Carnival in seedling tests, cv. Triumph was susceptible, whereas cv. Carnival was relatively resistant. Cv. Medallion was the only winter barley resistant in these tests.

Rhynchosporium of Barley

Virulence at the seedling stage to BRR-5 carried by test cv. La Mesita and cvs. Magnum, Corgi and Pipkin was detected for the first time.

Net Blotch of Barley

All winter barleys with current relevance to UK farming had high corresponding frequencies of virulence in seedling tests. One isolate from cv. Kym grown in Scotland gave distinctive spotting lesions. In adult plant field tests both winter and spring cultivars displayed a range of responses from highly susceptible to resistant.

Mildew of Oats

In a year of generally low incidence of oat mildew the most complex virulence combination OMR 1,2,3 (Race 5) virulent to all cultivars in commerce showed a drastic decrease in frequency, while the simpler OMR 1,2 (Race 3) avirulent on Avalanche and Milo showed an increase. However, these changes could be due to restricted sampling. No virulence was found to the Avena barbata resistance factor OMR 4 as in 1982. Adult plant tests revealed possible adaptation to the Milo resistance, whereas Rhiannon with the same specific resistance factor showed high resistance levels to all isolates.

Crown Rust of Oats

Two previously detected races were identified from the five samples tested.

MILDEW OF WHEAT

Fiona G.A. Bennett and Thea M.C. van Kints

Plant Breeding Institute, Cambridge

Analysis of conventional leaf samples indicated that Mission possessed WMR 4 and Hammer possessed WMR 7. Both cultivars appear to have additional unidentified resistance. Analysis of isolates pathogenic on Stetson proved that it also contains WMR 7 in addition to unidentified resistance, not WMR 2+6 and different from that in Hammer.

Reduced survival of WMV 7, WMV 5+8+? and WMV 2+6+7 in maintained isolates was confirmed. Pathogenicity matching Stetson resistance was also reduced whilst WMV 6 was dramatically increased in these isolates. It was recommended that direct methods should be used to estimate population pathogenicity in future. A negative association between insensitivity to triadimenol and WMV4, 2+4+6, 5+8+? and pathogenicity matching Mission was again indicated.

A general increase in insensitivity to triadimenol was noted in East Anglia mildew populations over the past three years. This was supported in tests of unselected populations collected in the wind impaction spore trap (WIST). It was found that the trap cultivar, the concentration at which it had been treated, the area in which trapping occurred and possibly the period of trapping all influenced the numbers of insensitive phenotypes and the range of their insensitivity.

The method of maintenance of insensitive isolates was investigated.

INTRODUCTION

Two new cultivars with unidentified resistance, Mission and Hammer, were included as differentials (Table 1) and Crossbow was removed from the current differential set.

Wet, cold conditions in spring prevented the widespread foliar infection observed in the previous winter, especially on early sown crops (ADAS Disease Intelligence Reports), from causing concern until ear emergence. Ear infection was commonly observed. A larger number of leaf samples were received (Table 2), compared with 1982, the majority arriving between 14 June and 21 July. It is notable that 6 out of 7 cultivars recommended for general use by the NIAB were reported by ADAS to be 'susceptible' to mildew in 1983.

In this paper, the term pathogenicity is used to denote the ability of a parasite to injure a host. This meaning is generally accepted throughout plant pathology so that, with the addition of appropriate adjectives, its use should not cause confusion. Unfortunately, the term virulence now has several different meanings and connotations and may thus lead to some misinterpretation. In the context of this paper, mean pathogenicity is equivalent to virulence measured as the number of colonies produced by an isolate on a given cultivar, expressed as a percentage of the number of colonies produced on cv. Hobbit (the susceptible control). The components of pathogenicity have been discussed in greater depth elsewhere (Bennett, 1980).

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

WMR group	Gene	Differential cultivar
0	-	Hobbit
1	Pm1	Anfield$^{\phi}$
2	Pm2	Bounty$^{\phi}$
3	Pm3a, 3b, 3c	Asosan$^{\phi}$, Chul$^{\phi}$, Sonora$^{\phi}$
4	Pm4a, 4b	Khapli$^{\phi}$, Armada
5	Pm5	Hope
6	Pm6	Timgalen
-	Pm7	Transec$^{\phi\dagger}$
7	Pm8	Stuart
8	'M1i'*	Flanders
9	Pm2+'M1d'	Maris Dove$^{\phi}$
2+4		Sappo$^{\phi}$
2+6		Brigand
4(+?)		Mission
7+?		Stetson
7+?		Hammer
5+8+?		Sicco
2+4+6		Timmo
2+6+7		CWW1645/5
2+6+8		Crossbow$^{\phi}$

$^{\phi}$ Not included in tests for this report: not relevant to commercial cultivars

† Not tested by present authors

* Temporary symbols

METHODS

Details of conventional leaf samples received and WIST (wind impaction spore trap (Bennett & van Kints, 1981) samples collected are given in Tables 2 and 3 respectively. In addition to the cultivars shown in Table 3, several other resistant cultivars were exposed in order to obtain isolates with matching pathogenicity. Such isolates are now available for Axona, Chul, MD 37 (a sister line of MD 2, made available to breeders in 1983 through BAPB) and Musket.

All samples from untreated host material were maintained on the susceptible cv. Cerco. WIST samples collected on triadimenol treated material were all maintained on Cerco treated with triadimenol at the rate of 0.04 g a.i. kg^{-1} seed.

Differential tests were carried out as described previously (Bennett & van Kints, 1982), colony numbers being counted automatically and mean pathogenicity values subsequently calculated. Fungicide insensitivity tests were also carried out as described previously (Bennett & van Kints, 1983) colony numbers being counted visually.

Table 2. Details of conventional leaf samples received in 1983

WMR Group	Source Cultivar	Received	Fungicide treated	Failed to establish	Died in culture
0	Moulin	5		1	2
	Rapier	7		3	1
2	Avalon	5		2	2
	Fenman	3		2	0
	Galahad	3		1	0
	Longbow	4		3	0
	Norman	5		1	1
4	Armada	5		2	0
	Sarsen	1		0	0
8	Aqulia	6		2	0
	Flanders	4		3	1
2+6	Brigand	4		3	0
	Huntsman	1		0	1
	Hustler	4		3	0
	Virtue	4		1	1
4(+?)	Mission	8		3	2
7+?	Hammer	5		4	0
	Stetson	8	1*	3	0
5+8+?	Sicco	1		1	0
2+4+6	Timmo	1		1	0
?	Musket	1		0	1
	Total	85	1	39	12

* Tilt

RESULTS AND DISCUSSION

Differential tests

1. Conventional leaf samples

Results obtained by testing samples on detached leaf segments of differential cultivars are shown in Table 4. The performance of isolates on Mission suggest that it belongs to WMR 4, like cv. Armada. This is supported by the knowledge that Mission is the product of an Armada cross (N.H. Chamberlain, personal communication). However, one isolate from Avalon was pathogenic on Armada but not on Mission indicating the possible presence of an additional unidentified resistance gene in Mission. Further tests are required to confirm this observation.

One isolate from Hammer was highly pathogenic on all differentials. The susceptibility of the WMR 7 differential to this isolate suggests that Hammer possesses WMR 7, since previous surveys (e.g. Bennett & van Kints, 1982) have shown that WMV 7 remains rare in populations unless direct selection is exerted by matching race-specific resistance. Five isolates

from cv. Stetson also gave high mean pathogenicity on the WMR 7 differential, confirming previous observations that this cultivar has WMR 7 resistance. Other evidence (unpublished) shows Stetson also possesses additional unidentified resistance.

Table 3. Details of WIST samples collected in 1983

WMR Group	Trap cultivar	Seed treatment (triadimenol)	No.	Failed to establish	Died in culture
0	Cerco	Untreated	65	0	12
		0.04	62	0	18
		0.125	52	0	6
0	Hobbit	Untreated	37	0	3
		0.04	10	0	4
		0.08	7	0	1
		0.125	7	0	1
		0.25	4	0	1
		0.625	1	0	0
3	Chul	Untreated	8	0	1
7+?	Stetson	Untreated	9	0	4
7+?	Hammer	Untreated	1	0	0
2+4	Sappo	Untreated	2	0	0
?	MD2	Untreated	1	1	0
?	Axona	Untreated	1	0	0
?	Valdur (T. durum)	Untreated	1	0	0
	Total		268	1	51

Table 5 shows the results of tests of 10 Stetson isolates, from both leaf and WIST samples. As six isolates were not pathogenic on WMR 2+6 or 2+6+7 differentials, Stetson does not belong to WMR 2+6+7 (Bennett & van Kints, 1983). The isolates all had WMV 5 and WMV 8 pathogenicity implicating the matching WMR groups in the resistance of Stetson. However, these pathogenicity characters are generally common (Table 4) so further work is required to determine precisely the resistance combination in Stetson. In five out of seven tests where Hammer was included, Hammer was not susceptible showing that although it shares WMR 7 with Stetson, the unidentified resistance is different from that of Stetson.

When means were calculated for the columns in Table 4, but excluding values for samples from cultivars with resistance matching that of the differential in question, an overall estimate of mean pathogenicity of WMV characters was obtained (upper half, Table 6). This method for estimating population pathogenicity is subject to various errors, as has been discussed previously (Bennett, 1978). Particularly noticeable in this context are the fluctuating values for WMV 2+6+7. In 1983, pathogenicity for WMR 2+6+7 was artificially inflated by samples from Stetson which could not be excluded since it was shown (Table 5) that Stetson did not possess WMR 2+6 in addition to WMR 7.

2. WIST samples

An improved, less biased estimate of mean pathogenicity values was obtained from analysis of WIST samples (lower half, Table 6). In common

Table 4. Mean pathogenicity of 34 bulk isolates received in 1983

WMR Group	Source cultivar	Wheat mildew virulence (WMV) group as represented by differential cultivars*												Number of isolates
		2	4	5	6	7	8	2+6	5+8+?	2+4+6	2+6+7	Stetson	Mission	Hammer	
0	Rapier	93	30	68	49	1	84	49	15	0	0	1	20	0	4
	Moulin	93	0	70	101	1	59	81	47	0	0	0	0	0	2
2	Avalon	96	41	50	47	0	47	88	13	0	1	0	0	0	3
	Fenman	60	0	0	51	0	33	41	0	0	0	0	0	0	1
	Galahad	77	1	78	41	0	95	89	1	0	0	0	2	0	2
	Longbow	115	0	115	114	0	71	116	0	0	0	0	0	0	1
	Norman	102	93	92	41	<1	89	52	5	0	0	0	72	0	3
4	Armada	134	135	69	104	0	116	142	27	26	1	0	115	0	3
	Mission	87	99	67	77	0	105	72	86	120	0	0	99	0	3
8	Aquila	91	81	90	82	0	91	115	67	45	0	0	71	0	4
2+6	Virtue	91	0	98	105	0	77	90	0	0	0	0	0	0	1
	Brigand	131	0	14	38	0	4	87	0	0	1	0	1	0	1
7+?	Hammer	89	105	124	125	125	108	94	91	77	115	116	94	81	1
	Stetson	40	15	75	27	101	79	21	24	0	39	86	17	7	5

*Differential cultivars given in Table 1.

Table 5. Pathogenicity, averaged over 4 test leaf segments, of Stetson isolates† taken from a) conventional leaf samples from plots or crops of cv. Stetson b) seedlings of cv. Stetson exposed in the WIST on transects in eastern and central England during May and June 1983

Type of sample	Isolate number	WMV group as represented by differential cultivars*											
		2	4	5	6	7	8	2+6	5+8+?	2+4+6	2+6+7	Stetson	Mission	Hammer
Leaf	(30	0	77	54	1	86	67	0	0	0	5	86	51	0
	(45	86	0	106	63	110	81	45	94	0	79	100	–	–
	(46	0	0	92	50	119	79	0	0	0	19	65	–	–
	(67	43	0	76	0	75	122	4	0	0	3	125	0	1
	(81	69	0	49	23	116	48	54	24	0	90	52	0	21
WIST	(50	76	0	97	4	119	92	4	46	0	13	157	0	0
	(68	62	0	25	0	83	45	1	0	0	3	94	0	1
	(80	82	1	47	34	91	20	61	0	0	72	40	0	41
	(91	89	0	116	98	131	108	92	1	31	96	59	–	–
	(103	155	0	79	0	206	94	0	37	0	0	99	0	0

* Differential cultivars given in Table 1

† Isolates maintained on detached leaf segments of cv. Stetson

Table 6. Comparison of mean pathogenicity of conventional leaf samples (excluding values for samples from cultivars with matching resistance) with WIST samples from untreated cv. Cerco seedlings 1980-82

Type of sample	Year	WMV group as represented by differential cultivars*													Number of isolates
		2	4	5	6	7	8	2+6	5+8+?	2+4+6	2+6+7	Stetson	Mission	Hammer	
CPVS - leaf samples	1980	72	22	54	35	4	56	48	31	7	-	-	-	-	114
	1981	77	37	65	64	1	58	82	29	22	4	-	-	-	32
	1982	86	15	63	59	0	64	71	13	2	1	0	-	-	18
	1983	85	37	73	64	<1	80	75	30	20	6	<1	26	1	35
mean	80-83	76	26	60	47	2	61	60	29	11	4	<1	26	1	(199)
WIST -trap samples	1980	73	45	68	30	6	68	57	29	12	-	-	-	-	38
	1981	85	53	89	68	2	75	57	37	13	2	-	-	-	28
	1982	96	35	68	73	2	80	96	16	17	1	2	-	-	17
	1983	89	42	69	72	1	67	75	20	14	0	0	33	1	36
mean	80-83	84	45	73	58	3	71	68	26	14	1	1	33	1	(119)

*Differential cultivars given in Table 1.

with previous years' results, WIST values were generally higher than those from leaf samples. This difference was probably due to selection against certain WMV types in established infections on non-matching hosts (Bennett & van Kints, 1981). Unusually, there were zero values for pathogenicity matching WMR 2+6+7 and Stetson. The latter result was surprising in view of the frequently observed infection of cv. Stetson in the field. It is possible that the Stetson resistance is more effective in seedlings than adult plants which would account for the lack of matching pathogenicity in populations except where populations were selected on Stetson itself.

3. Direct and indirect differential tests

Confirmation was sought of results obtained previously (Bennett & van Kints, 1983), which indicated differential survival of certain pathogenicity characters in laboratory-maintained populations. The results are shown in Table 7.

Table 7. Comparison of mean pathogenicity of samples tested directly, by counting colonies on differential cultivars exposed in the WIST, with sub-samples of the same populations tested indirectly in the laboratory after five to nine generations of maintenance

Testing method	WMV group as represented by differential cultivars*										No. of Samples
	7	5+8+?	2+6+7	Stetson	6	2	4	8	2+6	2+4+6	
Direct	13	40	24	6	15	179	63	84	141	24	21
Indirect	2	16	3	0	73	122	71	78	115	35	21
% change after maintenance	-85	-60	-88	-100	+387	-32	+13	-7	-18	+46	

*Differential cultivars given in Table 1

In order to match direct and indirect tests as nearly as possible, sub-samples of populations tested directly were taken from Hobbit, the susceptible control cultivar, immediately after assessment. They were then maintained on cv. Cerco until indirect tests were performed five to nine generations later. It was confirmed that WMV 7, 5+8+? and 2+6+7 types are selected against during maintenance of bulk isolates. Pathogenicity matching Stetson appeared to be at the same disadvantage. However, WMV 6 pathogenicity was dramatically increased in maintained isolates. Such a change was also hinted in the 1982 results (Bennett & van Kints, 1983). Other WMV types did not appear to change significantly. The decrease in WMV 2+4+6 pathogenicity observed in samples collected later in the 1982 season was not repeated in 1983. The 1982 result was probably a chance observation due to the small number of samples. The results presented in Table 7 show that direct differential tests of population samples will give more reliable information in future and that isolates from leaf samples should be given priority for testing as soon after collection as possible.

4. The effect of host seed treatment on pathogenicity

As in 1981 and 1982, comparison was made of mean pathogenicity of WIST samples collected on triadimenol treated and untreated seedlings (classified as insensitive and sensitive isolates respectively). Results from several sets of samples (Table 8) confirmed a negative association between fungicide insensitivity and WMV 4, 2+4+6, 5+8+? and Mission

pathogenicity (WMV 4+?). It is interesting that WMV 4 was involved in three out of these four instances, indicating that WMR 4 cultivars would particularly benefit from fungicide treatment. In order to prove this association, samples with high and low WMV 4 pathogenicity will be compared for insensitivity in 1984. The positive association between WMV 2+6 and insensitivity noted in 1981 and 1982 was not observed in 1983, possibly because the area sown to WMR 2+6 cultivars, and therefore the frequency with which they received fungicide treatment, declined.

Table 8. Mean pathogenicity matching selected host resistances in samples collected in the WIST on untreated (-) and treated (+) seedlings of different cultivars, at different times and in different areas

Trap Cultivar	Conditions of sample collection	WMV group as represented by different cultivars*											
		4		2+4+6		Mission		5+8+?		Mean others†		No. of samples	
		-	+	-	+	-	+	-	+	-	+	-	+
Hobbit	All	54	18	22	0	43	6	24	1	46	41	31	13
Cerco	All	42	16	14	3	33	16	20	8	42	43	36	52
Cerco	Matching	48	15	16	3	35	16	16	12	43	47	21	30
Cerco	Cambs	52	7	30	0	29	8	29	9	42	42	9	16
Cerco	Essex	33	16	11	1	30	18	22	8	41	46	16	16
Cerco	Pre-15 June	58	14	26	1	44	15	23	3	43	44	14	19
Cerco	Post-15 June	32	17	7	5	26	16	18	10	41	42	22	33

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

Fungicide insensitivity tests

1. Direct tests with the WIST

Sampling of the air spora for insensitivity to the sterol inhibiting (SI) fungicide triadimenol, has been carried out for three years and the data are presented in Table 9. A steady increase in both the number of insensitive individuals and the level of their insensivity has occurred, probably as a result of increased usage of SI fungicides. More detailed results of the direct sampling in 1982 and 1983 are shown in Figure 1.

Table 9. Mean percentage of colonies which grew on trap seedlings of cv. Cerco treated with triadimenol at the stated dose relative to those which grew on untreated control seedlings of cv. Cerco, all exposed in the WIST at intervals between May and August, 1981-1983, in Cambridgeshire

Year	Dose rate (g a.i. kg^{-1})*		
	0.025	0.04	0.125
1981	15	-	1
1982	48	25	6
1983	-	51	18

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

Figure 1. Mean colony number per seedling on cv. Cerco seedlings grown from seed treated with 0.04 g a.i. and 0.125 g a.i. triadimenol kg^{-1} seed expressed as a percentage of that on untreated Cerco seedlings when seedlings were exposed in the WIST on a) 80 km Cambridge transect b) 190 km Essex transect on dates between 1 June 1982 and 8 December 1983

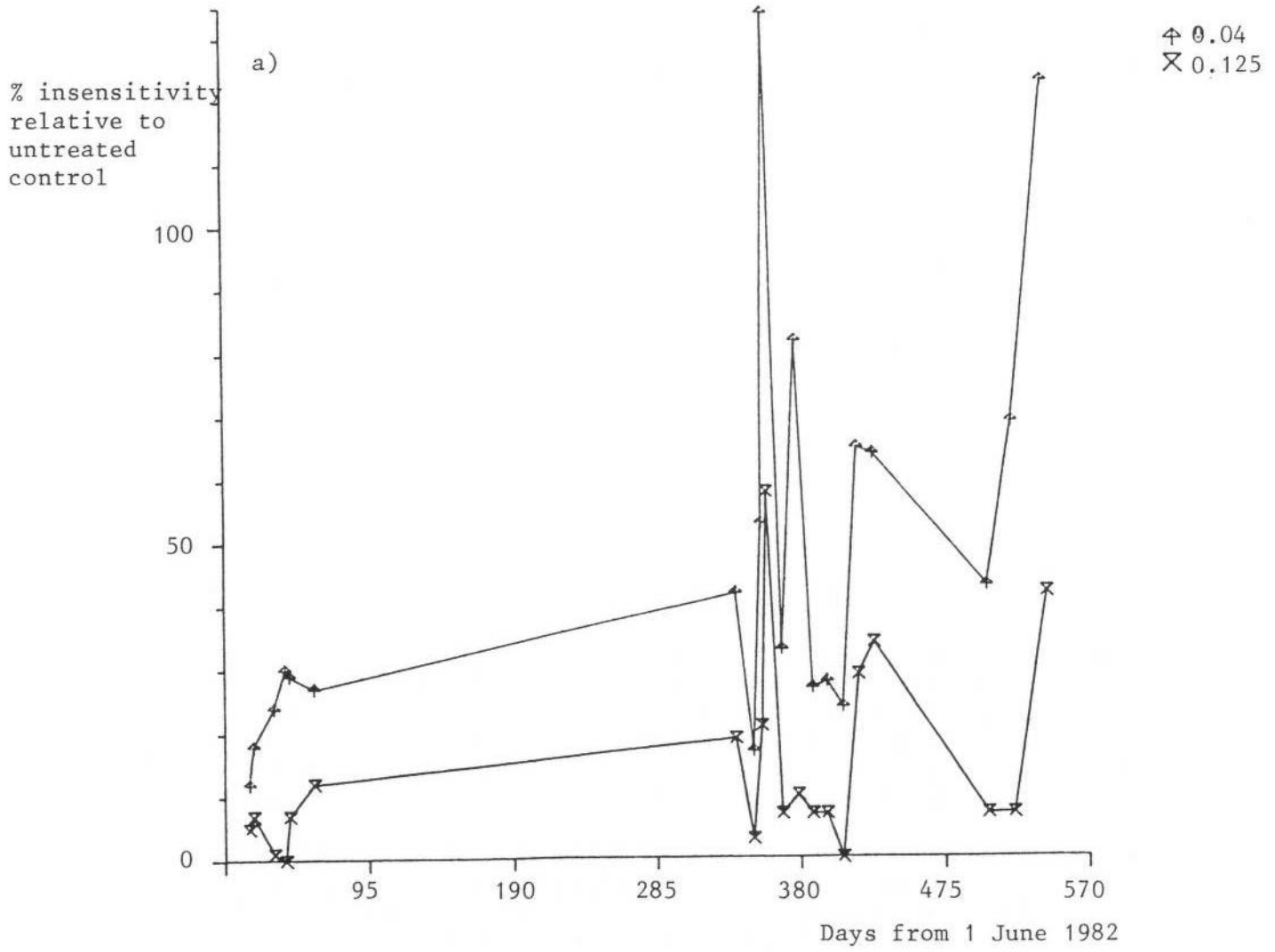
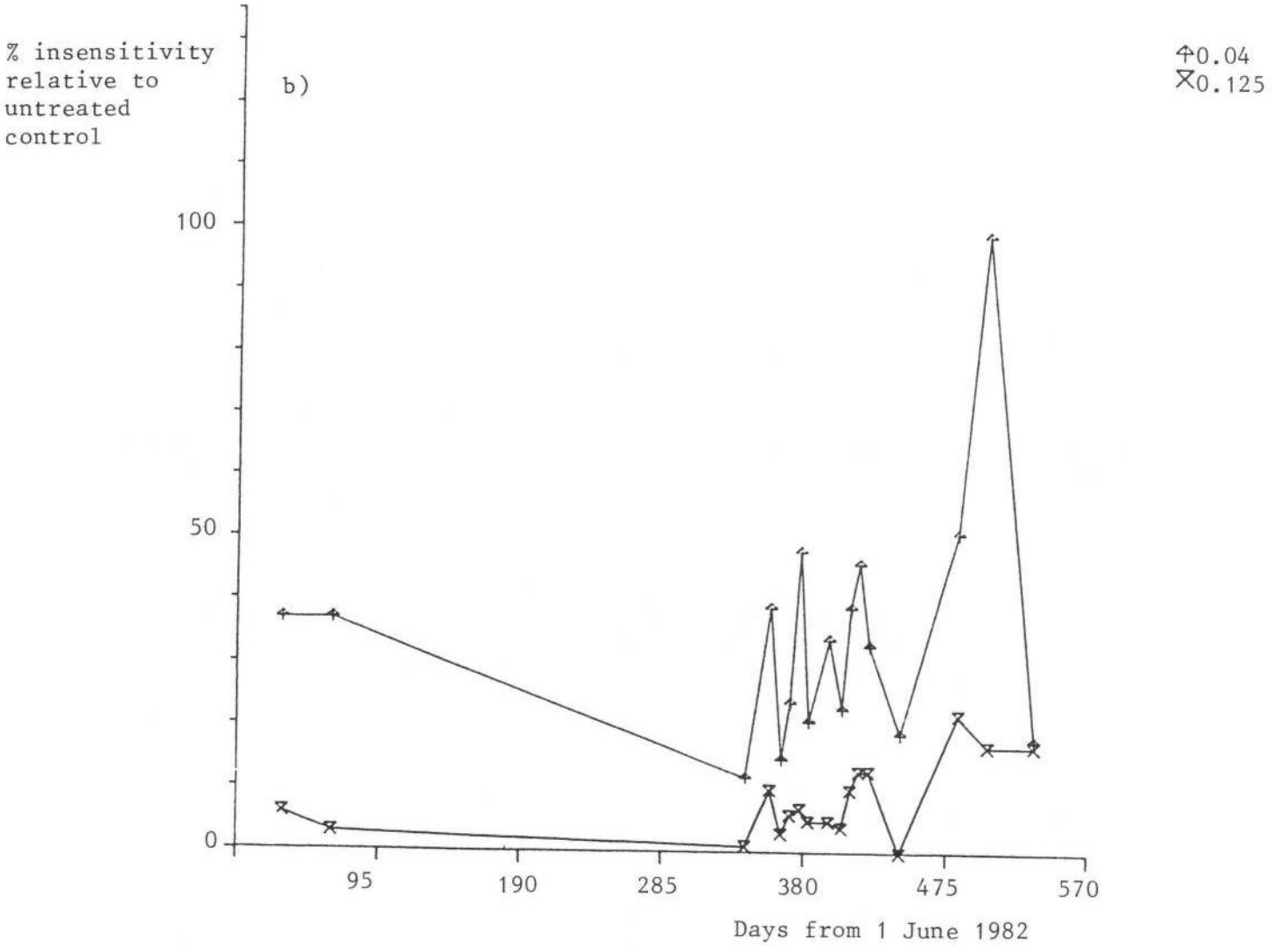


Figure 1 (continued)



Fluctuations during the season were probably partly due to variation in the overall concentration of fungicide in the field at different times. Another possible source of error is differences in uptake of chemical by the trap seedlings. Thus firm conclusions cannot be drawn from this data but when taken in conjunction with evidence from indirect tests (see below), it may be said that there was a general tendency for an increase in insensitivity to triadimenol in these mildew populations.

There is some evidence of an increase in insensitivity to triadimefon (an SI fungicide closely related to triadimenol) in Germany and the Netherlands and this may be responsible for an apparent reduction in effectiveness of the chemical in these countries (M.S. Wolfe, personal communication). However, no reports of reduced effectiveness of the chemical in the UK are known.

As in 1982, the highest numbers of insensitive individuals were present in populations in East Anglia and the north-east, and the lowest in Kent and Scotland, coinciding well with areas of high and low intensity of wheat-growing.

2. Indirect tests of isolates collected in the WIST

Comparison of insensitivity in matching isolates collected on untreated and treated material shows that insensitive phenotypes are at a disadvantage, compared to sensitive ones, on untreated material (Table 10). This was also observed in 1982. However, numbers of insensitive individuals collected on untreated material, and the range of their insensitivity, increased in 1983. In other words, insensitive phenotypes had apparently become more competitive over the intervening winter. However,populations selected on treated material have apparently reached a threshold with respect to insensitivity. It remains to be seen whether further selection pressure, for example from treatment of seed with triadimenol by growers, will alter this situation.

Table 10. Colony numbers on leaf segments grown from triadimenol-treated seed as a percentage of those on untreated segments for bulk isolates collected in the WIST on treated and untreated seedlings of cv. Cerco on corresponding circuits

Seed treatment of WIST seedlings†	Year	Treatment concentration of test seedling segments* 0.004	0.08	0.125	0.25	0.375	0.625	Number of Isolates
-	1982	13	2	<1	0	0	0	16
	1983	25	7	7	1	1	0	11
+	1982	62	41	26	5	1	0	24
	1983	59	33	16	4	<1	0	22

† - = untreated; + = seed treated with triadimenol
* All test seedlings were cv. Hobbit

Results of investigations made into the effect of trap cultivar, the dose rate at which the trap cultivar was treated and the period and area of trapping on insensitivity of populations are given in Tables 11, 12 and 13. Trap cultivar did appear to have an effect but only when it was

untreated or treated at lower dose rates, Cerco selecting more insensitive phenotypes than Hobbit (Table 11). There was a positive correlation between the treatment concentration of trap seedlings and the proportion of insensitive phenotypes up to a threshold treatment concentration of 0.125 g a.i. kg^{-1} seed (Table 11).

Samples collected after the major application of SI fungicides to wheat crops, compared with those collected before, appeared to confirm the increased proportion and range of insensitivity (Table 12), observed in 1982 (Bennett & van Kints, 1983). This effect was most obvious in samples collected on untreated seedlings and seedlings treated at 0.125 g a.i. kg^{-1} seed. However, it is not known why samples collected on seedlings treated at 0.04 g a.i. kg^{-1} seed did not give similar results. The area in which samples were collected also had an effect on insensitivity with populations in Essex showing larger numbers of insensitive phenotypes than those in Cambridgeshire (Table 13), presumably connected with increased usage of fungicide in the Essex area.

Table 11. Colony numbers on leaf segments grown from triadimenol-treated seed as a percentage of those on untreated segments for bulk isolates collected in the WIST on cv. Cerco, or cv. Hobbit seedlings grown from untreated seed and seed treated at the stated concentrations

Trap cultivar	Treatment concentration of trap seedlings	Treatment concentration of test seedling segments*						Number of Isolates
		0.04	0.08	0.125	0.25	0.375	0.625	
Cerco	(Untreated	22	7	7	1	2	0	24
	(0.04	55	26	11	2	0	0	43
	(0.125	64	44	16	4	1	0	40
Hobbit	(Untreated	14	4	2	0	0	0	18
	(0.04	34	5	1	0	0	0	5
	(0.08	68	28	4	0	0	0	5
	(0.125	70	32	20	1	4	1	6
	(0.25	61	24	14	0	0	0	4
	(0.625	71	26	4	0	0	0	1

*All test seedlings were cv. Hobbit

Table 12. Colony numbers on leaf segments grown from triadimenol-treated seed as a percentage of those on untreated segments for bulk isolates collected in the WIST on cv. Cerco seedlings grown from untreated seed and seed treated at two different concentrations before and after 15 June 1983

Treatment concentration of trap seedlings	Period of sampling relative to 15 June	Treatment concentration of test seedling segments*						Number of Isolates
		0.04	0.08	0.125	0.25	0.375	0.625	
Untreated	Before	5	2	0	0	0	0	5
	After	27	9	8	1	2	0	19
0.04	Before	63	34	13	3	0	0	13
	After	52	23	10	2	0	0	30
0.125	Before	58	27	12	2	0	0	14
	After	68	53	18	5	2	0	26

*All test seedling segments were cv. Hobbit

Table 13. Colony numbers on leaf segments grown from triadimenol-treated seed as a percentage of those on untreated segments for bulk isolates collected in the WIST on cv. Cerco seedlings grown from seed treated at two concentrations and exposed on 80 km Cambridge transect or 190 km Essex transect from May until August 1983

Transect	Treatment concentration of trap seedlings	Treatment concentration of test seedling segments*						Number of Isolates
		0.04	0.08	0.125	0.25	0.375	0.625	
Cambridge	0.04	42	14	9	0	0	0	10
	0.125	52	33	20	6	1	0	11
Essex	0.04	62	35	11	3	1	0	21
	0.125	81	53	16	4	2	0	16

*All test seedlings were cv. Hobbit

3. Method of maintenance of insensitive isolates

Following observations of the effect of laboratory maintenance on mean pathogenicity of bulk isolates (Table 7), it was considered necessary to determine what effect maintenance might have on insensitivity. Therefore 26 insensitive isolates were tested immediately after trapping and then divided in two, keeping one sub-sample on untreated Cerco and the other on Cerco treated at 0.04 g a.i. kg^{-1} seed. These sub-samples were subsequently tested after four to seven generations. More highly insensitive phenotypes were lost when samples were maintained on untreated material while small changes in proportions of insensitivity occurred when samples were maintained on treated material. Further investigation of this problem is required before firm conclusions can be drawn.

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YELLOW RUST OF WHEAT

Rosemary A. Bayles and Jane E. Thomas

National Institute of Agricultural Botany, Cambridge

98 samples were received during 1983, from which 63 isolates were made. The virulence combination WYV 1,9, first detected by the UKCPVS in 1982, was identified in 23% of isolates. These isolates were virulent on seedlings of the previously resistant cultivar Stetson (classified as WYR 1,9). In adult plant tests, Stetson was highly susceptible to isolate 82/29 (WYV 1,9). Eight new cultivars were compared with control cultivars and WYR factors were identified. Nine new isolates were tested and virulences compatible with adult plant resistances identified. One isolate possessed combined virulence for all three adult plant resistances, WYR 12, WYR 13 and WYR 14.

INTRODUCTION

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. Methods of detecting increased virulence and the current UK detection system have been described by Priestley (1978).

METHODS

Seedling tests with 1983 isolates

A total of 98 samples was received during 1983, which was about twice the number in 1982 and reflected the favourable conditions for disease development during the spring and early summer. The samples had been collected in a non-random way from Brigand (11 samples), Stetson (10), Hustler (9), Virtue (8), Longbow (7), Avalon (6) and 47 samples from 28 other varieties.

Isolates were made successfully from 63 samples. Seedling tests were carried out to determine the presence of virulence factors compatible with the overall specific resistances WYR 1 - 10 (Table 1). Fenman and Stetson were included as additional test cultivars, because they had been resistant to all isolates in previous years.

Adult plant tests with 1982 and control isolates

Sixteen isolates and an isolate mixture were tested for virulence compatible with adult plant resistances, using the Polythene tunnel technique described by Priestley and Byford (1978). The same isolates were tested in seedling tests in controlled environment chambers (16 hour day at 18°C, 8 hour night at 11°C). The isolates (Table 2) comprised seven controls of known virulence, four collected during the 1982 survey, two from inoculated plots in 1982 Polythene tunnel tests, a mixture of the remaining 1982 isolates, and three others.

In Polythene tunnel tests, two replicate tussocks of 36 cultivars were sown on 8-9 November, inoculated on 16 and 29 March, and assessed for percentage leaf area infection on 28 April (GS 35), 10 May (GS 40), 20 May (GS 46), 1 June (GS 62), 13 June (GS 70).

Table 1. Resistance factors to Puccinia striiformis

WYR Factor	Gene	Type*	Test cultivar	WYV detected
WYR 1	Yr 1	Overall	Chinese 166	1957
WYR 2	Yr 2	Overall	Heine VII	1955
WYR 3	-	Overall	Vilmorin 23	1932
WYR 4	Yr 3b + 4b	Overall	Hybrid 46	1965
WYR 5	Yr 5	Overall	T. spelta album	.
WYR 6	-	Overall	Heine Kolben	1958
WYR 7	Yr 7	Overall	Lee	1971
WYR 8	Yr 8	Overall	Compair	1976
WYR 9	Yr 9	Overall	Riebesel 47/51	1974
WYR 10	Yr 10	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

RESULTS

Seedling test with 1983 isolates

Sampling was not carried out on a random basis and the virulence frequencies shown for 1976-1983 (Table 3) should therefore be interpreted with caution. The apparent decline in WYV 1 and associated increase in WYV 4 commented on in last year's report was reversed. The apparent increase in WYV 1 was probably partly due to selective sampling from crops of cultivar Stetson (WYR 1,9). Two 1983 isolates possessed the unusual virulence combination WYV 1,4.

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

Code	Cultivar	Region *	Site	** WYV Factors
Control Isolates				
72/852	Maris Ranger	EM	Market Harborough	WYV 2,3,4,6,(7),12
76/71	Grenade	S	Mains of Ravensby	WYV 1,2,3,13
80/32	Bounty	EM	Grainthorpe	WYV 1,2,3,13
77/20	Maris Ranger	E	PBI Trial Ground	WYV 1,2,3,6
71/493	Capta	S	Duns	WYV 1,2,3,7
P 631	Maris Templar inoculated with YRW 74/16			WYV 1,(2),3,4,6,7
P 75/27	Hobbit inoculated with YRW 73/23			WYV 2,3,4,14
1982 Isolates				
82/13	Avalon	N	Shoreswood	WYV 2,3,4,6
82/27	Avalon	E	NIAB Trial Ground	WYV 2,3,4
82/43	Longbow	N	Beverley	WYV 1,2,3,6
82/29	Stetson	SE	Wye	WYV 1,2,3,9
Other Isolates				
P79/4	TL 363/30/2		PBI Trial Ground	WYV 1,2,3,14
P81/20	CWW 1335/2 (Moulin)		PBI Trial Ground	WYV (2),3,4,6,14
82/A3	Armada inoculated with 81/A1			WYV 2,3,4,8,9
P81/12	CWW/1684/15		PBI Trial Ground	WYV 2,3,4,6,13,14
82/A1	Norman inoculated with 76/15			WYV 1,2,3,6, (7)
83M	Mixture of 1982 isolates			

( ) = partially virulent on corresponding resistance

* = S Scotland, EM East Midlands, E East, N North, SE South East.

** = Results from previous years' information. For 1982 isolates data are from seedling differential tests only.

There was a substantial increase in the frequency of WYV 9, due largely to samples collected from the cultivar Stetson (WYR 1,9). All WYV 9 isolates from the 1983 survey also possessed WYV 1, regardless of source cultivar. The combination WYV 1,9 was first detected by the UKCPVS in 1982 (ie isolate 82/29) all earlier UK isolates, from 1975-1981, having been of the WYV 2,3,4,9 type (plus or minus WYV 8). Race 169E136, equivalent to WYV 1,9, has been identified regularly in Europe since 1977 (Stubbs, 1977). Johnson et al (1980) have also reported a WYV 1,9 isolate (race 171E138) from a sample taken from the trial ground of the Plant Breeding Institute. It appears therefore that the frequency of the virulence combination WYV 1,9 could rise rapidly in response to an increased acreage of cultivars possessing the corresponding resistance factors. There is evidence that virulence for Stetson is already becoming common and that the cultivar is potentially very susceptible. No isolates were virulent on Fenman.

Table 3 Virulence factor frequency (%)

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

Adult plant tests with 1982 and control isolates

Infection data are given in Table 4.

Cluster analysis was used to display the relationships between cultivars in the form of a minimum spanning tree (Fig 1). In the analysis, isolates were treated as separate variates from which to calculate a matrix of similarity coefficients for cultivars. The minimum spanning tree shows relationships between individuals in the form of a network in which they are joined by a set of straight lines, the lengths of which are proportional to the dissimilarity between adjacent individuals. The potential of this technique as an aid to sorting cultivar x isolate data has already been discussed (Priestley, Bayles and Crofts, 1982) and it has been adopted this year in preference to the dendrograms presented in earlier reports.

In the minimum spanning tree (Fig 1), dotted boundaries have been drawn to encompass cultivars believed to possess similar resistances. Boundaries were first defined using the positions of well documented cultivars with established resistances. The position of new cultivars in relation to these boundaries indicated their likely resistances, which were then checked by inspection of the original infection data (Table 4) for appropriate cultivar x isolate interactions. In this way, boundaries were extended to include new cultivars as shown in Figure 1. Cultivars which were resistant to all isolates are clustered closely together in the centre of the tree. Two long side branches

link WYR 6 cultivars and WYR 13 cultivars and a number of shorter branches and more diffuse clusters can be distinguished (WYR 9, WYR 7, WYR 12 and WYR 14). The analysis has also been successful in placing cultivars possessing two specific resistances in appropriate positions with respect to both. This is shown by the overlapping orbits in Figure 1 e.g. WYR 1/WYR 13; WYR 4/ WYR 14. Within any one branch, susceptibility tends to increase with distance from the centre of the tree.

One of the main applications of this type of cluster analysis is in the elucidation of relationships between new cultivars and established control cultivars. In 1983, 10 new cultivars were tested alongside 26 others and the spanning tree was of considerable assistance in grouping these appropriately, (Table 4). There are obvious implications for the construction of cultivar diversification schemes.

Seven cultivars (Table 4 - Aquila to Baron) showed good resistance to all isolates as adult plants, although differing in seedling reactions. This group included 4 cultivars tested for the first year, Mission, Meteor, Brimstone and Dalec.

Cultivars Bilbo to Galahad comprise a group possessing WYR 14 in combination with different overall resistances. Bilbo and Hobbit (WYR 14) interacted with isolates in Box A. Brigand (WYR 2,14) interacted with the same set of isolates with the exception of P81/20 (Boxes B). This and other evidence indicates that WYV 2 was less effective in P81/20 than had been expected from the results of seedling tests. The identification of the resistance of Rapier as WYR 2,4,14 was confirmed (Boxes C). There is some indication that P81/12 showed increased virulence for Brigand and Rapier, but this may have been a non-specific effect, since the isolate also produced higher levels of infection than any other on Michigan Amber (WYR 0). Moulin interacted markedly only with those WYV 14 isolates which also possessed WYV 6, (Box D), although at the seedling stage this interaction was inconsistent. The identification of the resistance of Galahad as WYR 1,14 was confirmed (Box E). There were no new cultivars in the WYR 13 group, which interacted with isolates in boxes F and G. The apparent interactions of Hustler and Virtue with 72/852 were attributable to contamination.

The new cultivar Sarsen appeared to be similar to the WYR 12 cultivars Mega and Armada, which interacted with isolates in boxes H.

Cultivars possessing WYR 9 interacted with isolates in Boxes J, K and L. Stetson, which possesses WYR 1 in addition to WYR 9, interacted only with 82/29, to which it was very susceptible, (Box L). Hammer and Stuart also showed significantly higher levels of infection with 82/29 than the other WYV 9 isolate, although they were susceptible to both at the seedling stage, (Box K). Clement was equally susceptible to the two isolates (Box J). This result suggests that Hammer and Stuart possess an adult plant resistance in addition to WYR 9 and that this is overcome by 82/29. The additional resistance could be WYR 1 expressed at the adult plant stage only, or a new resistance, as yet unidentified.

The new cultivars Brock and Renard were similar to Tommy, interacting with isolates in Box M and have therefore been classified as WYR 7.

WYR 6 cultivars interacted with isolates in Boxes N, P and Q. Norman and Longbow, which possess additional resistances WYR 2 and WYR 1,2 respectively were susceptible only to isolates possessing WYV 2,6 (Boxes P) and WYV

Table 4 Results of adult plant tests 1983

Values are percent leaf infection (mean of 5 assessment dates).

Identifications of WYR and WYV factors are based not only on results presented here, but also on others reported previously.

R = resistant to all isolates.
Rx = resistance not identified.

( ) = partial virulence.

Underlined figures indicate that the cultivar/isolate combination gave a susceptible reaction in seedling tests (type > 2.0). Figures not underlined gave a resistant reaction (type 0-2).

Boxes are used to mark apparent cultivar x isolate interactions in adult plant tests and have no statistical significance.

+ = contaminated with WYV 1 and WYV 13.

++ = contaminated with WYV 7. Earlier results have shown that 77/20 is virulent on WYR 6.

* = not tested at the seedling stage.

Table 4. Results of adult plant tests 1983

Cultivar	Isolate	P79/4	82/27	P75/27	82/13	P81/20
	WYV Factors	1,2,3,14	2,3,4,14	2,3,4,14	2,3,4,6,14	(2),3,4,6, 14
	WYR Factors					
Aquila	Rx	0	0	0	0	0
Mission	Rx	0	0	0	0	1
Meteor	Rx	0	1	0	0	1
Brimstone	Rx	0	0	0	0	0
Fenman	R	0	0	0	0	1
Dalec	1	0	0	0	0	0
Baron	9	0	0	0	0	0
Avalon	4	0	6	7	4	10
Maris Beacon	4	1	18	14	12	8
Bilbo	14	23	21	11	11	23
Hobbit	14	15	6	10	7	14
Brigand	2,14	11	8	8	6	2
Rapier	2,4,14	1	4	3	3	0
Moulin	6?,14	1	0	2	6	14
Galahad	1,14	9	0	0	0	0
Maris Huntsman	2,13	3	1	3	5	1
Hustler	1,2,13	5	1	3	0	0
Virtue	1,13	8	0	1	0	0
Sarsen	12	0	0	0	1	0
Armada	12	0	0	0	1	3
Mega	12	0	1	0	1	4
Clement	9	1	0	0	0	0
Stuart	9	0	3	1	0	5
Hammer	9	0	0	0	0	0
Stetson	1,9	0	0	0	0	0
Brock	7	0	0	0	0	1
Renard	7	0	0	0	0	1
Tommy	7	0	0	0	0	4
Kinsman	6	0	0	1	13	8
Freeman	6	0	0	1	8	11
Ranger	6	0	1	2	8	12
Norman	2,6	0	0	0	9	1
Longbow	1,2,6	0	0	0	0	0
Maris Templar	1	12	0	3	0	0
Cappelle Desprez	3	12	7	5	2	7
Michigan Amber	0	20	19	15	24	16

A, B, C, D, E, P

	P81/12	82/43	77/20++	82/A1	P631	71/493	80/32	76/71	72/852+	82/A3	82/29	Mixture
	2,3,4,5,12, 13,14	1,2,3,6, 13	1,2,3,6	1,2,3,6, (7)	1,(2),3,4, 6,7	1,2,3,7	1,2,3,13	1,2,3,13	2,3,4,6, (7),12	2,3,4,8, 9,12	1,2,3,9	
	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	6	0	0	0	0	0	0	0	0	2
	0	1	0	0	0	0	0	1	0	0	1	0
	9	0	2	0	5	4	1	0	1	3	0	6
	7	0	2	0	7	8	0	0	2	21	3	13
	17	9	9	8	12	11	11	15	11	9	10	18
	12	11	11	10	14	13	12	11	12	10	9	9
7	B	5	2	1	4	5	6	3	5	2	4	7
2	C	0	0	0	4	3	0	0	0	1	0	4
2		0	0	1	2	2	0	0	0	0	0	6
0		0	0	0	1	2	0	0	0	0	2	6
0	F	10	2	3	3	6	15	F 11	4	2	4	8
0		6	2	1	3	2	14	12	9	2	4	11
5		10 G	8	5	8	6	13	12 G	12	5	7	13
6		0	0	0	0	0	0	0	3	1	0	4
5	H	0	0	0	0	0	0	0	8	5 H	0	3
5		11	11	10	12	11	10	10	16	16	12	3
0		1	0	3	8	9	1	4	0	33 J	38	12
2		2	0	0	2	4	0	1	0	5	18	3
0		0	0	0	0	0	0	0	0	1 K	10	0
0		0	0	1	3	2	0	2	0	0	22 L	0
0		0	0	0	5	6	0	0	0	0	0	0
0		0	0	0	5 M	5	0	0	3	0	1	0
0		0	9	0	25	17	0	0	0	0	1	0
5		22	8	10	5	1	0	0	5	1	5	9
1	N	8	8	11	12	1	0	0	11 N	0	1	4
0		10	9	16	16	0	1	2	13	0	3	7
2		13	13 P	10	3	0	0	0	0	0	1	7
0		12	4 Q	8	1	0	0	0	0	1	0	0
1		10	9	6	22	11	14*	10	5	1	12	0
4		7	7	9	13	6	11	4	9	4	10	5
5		20	18	14	20	18	16	24	24	29	32	22

1,2,6 (Box Q). The seedling test results given here for isolate 77/20 were at variance with previous experience of this isolate and with the adult plant test results, both of which indicate that 77/20 possesses the virulence combination WYV 1,2,6.

Nine isolates were tested for the first time in Polythene tunnel tests, including three from the Plant Breeding Institute (designated P).

Isolate 82/27 was similar to the control isolate P75/27 (WYV 2,3,4,14); 82/13 and P81/20 possessed the virulence combination WYV 2,3,4,6,14 and showed increased virulence for Moulin. Results confirmed that P79/4 possesses WYV 1,14 and has increased virulence for Galahad.

82/A3, a re-isolate from Armada, showed increased virulence for WYR 12 cultivars and also WYR 9 cultivars. 82/A1 was classified as WYV 1,2,3,6. 82/43 possessed the adult plant virulence WYV 13 in combination with WYV 6.

P81/12 was a widely virulent isolate possessing virulence for all three adult plant resistances WYR 12, 13, 14. This is the first time that combined adult plant virulence has been confirmed in Polythene tunnel tests, although it still remains undetected in survey samples.

82/29 possessed the virulence combination WYV 1,9 and was virulent on the previously resistant cultivar Stetson, as discussed earlier in the report.

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BROWN RUST OF WHEAT

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

Welsh Plant Breeding Station, Aberystwyth

Eighty six isolates of Puccinia recondita were tested on seedlings of 31 differential cultivars. The winter wheat cultivars Stetson and Hammer appear to possess the rye-derived resistance (WBR-1). The cv. Thatcher isoline carrying Lr 19 was resistant to all isolates. Resistance that only expressed at either high or low temperature was observed in several of the differential cultivars. Adult plant tests in field isolation nurseries suggest that cultivars Norman and Hobbit do not carry the same resistance as cvs Sentry and Maris Fundin (WBR-2) as suggested previously. Different patterns of response were observed between the Triticale lines indicating different resistance factors. Cvs Virtue, Hustler, Rapier and Moulin were resistant to all four isolates. 'Reception nurseries' were grown in controlled environments to allow earlier identification of increased virulence to cultivars possessing adult plant resistance. These nurseries also enabled the effect of temperature on the expression of resistance at post-seedling growth stages to be studied. Cultivars Virtue, Rapier and Hustler were found to carry similar resistance which is only expressed at adult plant stages and at relatively low temperatures (ca. 10°C). Isolates were identified which overcame the resistance of cvs Hustler, Rapier and Virtue under the test conditions.

SEEDLING TESTS WITH 1983 ISOLATES

The 94 samples of wheat brown rust was the highest number received since this disease was first included in the surveys in 1972. Twenty-nine of the samples were from cv. Avalon, virulence to which was first detected in 1980. The remainder were from a wide range of winter cultivars. The geographic origins of the samples are outlined.

Location	Number of samples
South	31
East	27
South East	21
East Central	6
South West	5
West Central	2
Unknown origin	2
Total	94

The isolates of Puccinia recondita were tested on the standard set of differential cultivars. Also included were cv. Thatcher backcross lines carrying different resistance factors, together with 7 other lines carrying resistance factors, which were received from Dr R.A. McIntosh, University of Sydney, Australia. Five winter wheat cultivars, which are either on the NIAB List of Recommended varieties or in recommended list trials, completed the set of test cultivars which are listed below.

Differential cultivars

Standard differential cultivars	Thatcher Lr lines	R.A.M. lines	Additional winter cultivars
Clement (WBR-1)	Lr 1	Gatcher (Lr 27)	Stetson (PG)
Maris Fundin (WBR-2)	Lr 2a	Thew (Lr 20)	Hammer
Norman (WBR-2)	Lr 3	Transec (Lr 25)	Mission (PG)
Hobbit (WBR-2)	Lr 3bg	CS 70/Ag#11 (Lr 29)	Galahad (PG)
Sappo (WBR-3)	Lr 3Ka	Tc+Lr 30(LrT) (Lr 30)	Moulin
Maris Halberd (WBR-4)	Lr 9	CS20/2M[(Lr 28)C77.1] (Lr 28)	
Gamin (WBR-6)	Lr 15	ST-1 sel.(CN78.113)SR susc.(Rye resist?)	
Sterna (WBR-7)	Lr 19		
Sabre (WBR-7)	Lr 24		
Armada			

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 were cultured from 86 samples; the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cv. Armada. Twenty isolates were fully compatible on cv. Clement (WBR-1). Cvs Stetson and Hammer were also susceptible only to these isolates, suggesting that they carry the same resistance which is derived from rye (Secale cereale).

Cvs Maris Fundin, Norman and Hobbit responded similarly to all isolates. Eight isolates confirmed the temperature-sensitive resistance of these cultivars, giving a fully susceptible reaction at the low temperature regime but giving a mixed resistant reaction at the high temperature regime.

The majority of isolates tested gave a mixed response on cvs Sappo (WBR-3) and Maris Halberd (WBR-4). The temperature-sensitive resistance of these two cultivars was confirmed, several isolates being less virulent at the low temperature regime. Nine isolates were identified which were fully compatible with cv. Sappo at both temperature regimes. The two resistances were differentiated by isolate WBRS-83-72. Cv. Gamin (WBR-6) was susceptible to all isolates.

Cvs Sterna (WBR-7) and Sabre showed a similar pattern of response, supporting previous evidence that they possess the same resistance factor(s) (Clifford, Nazim & Jones, 1982). The temperature-sensitive resistance of these cultivars was expressed at the higher temperature to all but four isolates.

In the Thatcher Lr backcross lines, Lr 19 was effective against all isolates. Resistance conferred by Lr 9 was effective against all isolates but to some it was only expressed at the higher temperature. High temperature resistance was expressed in carriers of Lr 1 and Lr 3.

In the R.A.M. lines, CS 20/2M-(Lr 28) was resistant to all isolates. Virulence to Transec (Lr 25) was found in one isolate only at the higher temperature. The temperature-sensitive resistance of Gatcher (Lr 27) was expressed at the low temperature regime.

Winter wheat cvs. Galahad, Mission and Moulin were susceptible to all isolates.

ADULT PLANT TESTS IN FIELD ISOLATION NURSERIES

Thirty-nine wheat cultivars, 37 winter and 2 spring, were grown in each of 4 isolation nurseries in 1982-83 using standard procedures. The cultivars included 8 Triticale breeding lines carrying unidentified factors for resistance to P.recondita. The four isolates used were:

Isolate	Origin
WBRS-82-24	ex Avalon, Oxon
WBRS-82-25	ex Armada, Hants (gave a high infection type in seedling tests to cv. Sabre (WBR-7)
WBRS-77-22	ex Aquila, Clement (WBR-1) virulent
WBRS-74-2	ex Huntsman, Morley. Huntsman (WBR-5) virulent

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

Results

These are summarised in Table 1.

WBR-1 cultivars: Clement, Aquila, Stetson and Hammer were susceptible to two of the isolates, both of which were Clement virulent in seedling tests. This suggests that cvs Stetson and Hammer possess WBR-1, an assumption which is supported by their responses in seedling tests. The resistance is of the overall type except in cv. Aquila where it is expressed only in post-seedling growth stages (Clifford et al., 1982).

According to R. Johnson (pers.comm.) the cultivars Clement, Stuart, Stetson, Baron, Hammer and, probably, Abele, all have resistance to brown rust derived from rye. This resistance has been named Lr 26, and it is linked to the genes Yr 9 for resistance to yellow rust and Pm 8 for resistance to powdery mildew. These genes are all located on a rye segment of chromosome translocated to chromosome 1B of wheat. Aquila does not possess this segment of rye chromosome and does not have Yr 9 or Pm 8. It seems highly unlikely therefore that it possesses Lr 26, and its reaction is not characteristic of Lr 26 which is effective in seedlings. Perhaps it should be put into a separate sub-group of WBR 1.

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

Cultivar	WBR factor	Isolate WBRS-82-24 $\bar{x}$ (%)	WBRS-82-24 Flag (%)	WBRS-82-25 $\bar{x}$ (%)	WBRS-82-25 Flag (%)	WBRS-74-2 $\bar{x}$* (%)	WBRS-74-2 Flag (%)	WBRS-77-22 $\bar{x}$ (%)	WBRS-77-22 Flag (%)
Clement	1	3	4	10	22	3	5	18	22
Aquila	1	0.2MS	0.3	4	8	0.2	0.3	9	10
Stetson	1	Tr	Tr	8	18	0.3	0.1	23	33
Hammer	1	0.1	0.3	3	8	1MS	3MR	11	15
Fundin	2	29	38	10	18	3	8MS	5	6MS
Sentry	2	12	18	8	15	7	10	3	3R
Norman		TrMS	4MR	3R	9R	2R	5R	0.3R	0
Hobbit		2MR	4MR	2MR	4MR	1MR	2MR	0	Tr
Sappo	3	3	6	-	-	-	-	0	0
Halberd	4	2	5	0	0	0	0	0	0
Huntsman	5	13MR	25MR	20	30	18	33	3	10MS
Brigand	5	15MR	27MR	19	30	27	47	8	12
Mardler	5	10MR	18MR	12	23	11	20	3MS	MS
Gamin	6	18	28	2	5	TrR	TrR	0	0
Sabre	7	Tr	0	0	0	0	0	Tr	1
Sterna	8	TrR	0	0.1	0.3	0	0	Tr	0
Maris Ranger	8	0	0	3	7	0.3MS	1MS	5	8
Avalon	9	23	35	3	8	Tr	Tr	Tr	0
Sportsman	9	19	32	0.7	1	0.1	TrR	Tr	0.5MR
Bounty	9	14	25	0.3MS	1MS	0.1R	0.3R	2R	3R
Moulin		TrR	0	0.1R	0.3R	0	0	TrR	0
Kinsman		TrR	Tr	1MR	2MR	0	0	5MR	6MR
Virtue		2R	5R	0	0	TrMR	0.3M	TrMR	0
Hustler		TrR	TrR	0.5R	1R	0.3	0	0	0
Rapier		TrR	1R	TrR	TrR	0	0	0	0
Galahad		1MS	1MS	11	18	9	18	7MS	12MS
Longbow		1R	3MR	8MS	17MS	7	15	3MS	2MS
Fenman		17	27	5	7	7	13MS	3	3MS
Mission		24	33	7	11	6	12	8	10
Flanders		24	37	11	20	9	18	10	13
Armada		30	40	17	33	14	28	13	18

$\bar{x}$ = Mean of 3 scoring dates; $\bar{x}$* = Mean of 2 scoring dates;
Flag = Final disease assessment on flag leaf; R = Resistant reaction type;
MR = Mixed reaction types, resistant; MS = Mixed reaction types, susceptible.

WBR-2 cultivars: This temperature-sensitive overall resistance was believed to be carried by cvs Maris Fundin, Sentry, Norman and Hobbit (Clifford et al., 1981). By their reactions to the isolates tested these cultivars can be divided into two distinct pairs (Fundin and Sentry in one and Norman and Hobbit in the other. Quantitative differences in infection have been observed between these cultivars to various isolates previously (Clifford et al., 1982). Polythene tunnel tests at NIAB, Cambridge confirm this distinction (Bayles & Priestley, 1983).

WBR-3, WBR-4 cultivars: Cvs Sappo and Maris Halberd gave a low level of infection to isolate WBRS-82-24, but were resistant to all other isolates. Results were incomplete for cv. Sappo.

WBR-5 cultivars: These include Maris Huntsman, Brigand and Mardler which were highly susceptible to isolates WBRS-82-25 and WBRS-74-2, but gave a more resistant response to the remaining isolates.

WBR-6 cultivars: Gamin was susceptible to isolate WBRS-82-24 but resistant to the other three isolates. This pattern of response is similar to cultivars possessing WBR-9. Cultivars within these two resistance groups also reacted similarly to isolates tested in 1982.

WBR-7 cultivars: All isolates were avirulent on Sterna and Sabre, the resistance of which has previously been shown to be temperature-sensitive.

WBR-8 cultivars: Maris Ranger, which possesses an adult plant resistance (Clifford et al., 1981) showed specific resistance to two isolates, and susceptibility to two isolates but with a low level of infection.

WBR-9 cultivars: Cvs Avalon, Sportsman and Bounty were all highly susceptible to isolate WBRS-82-24 which originated from cv. Avalon.

The resistance of cvs Virtue, Hustler, Rapier, Kinsman and Moulin was effective against all isolates.

Different patterns of response were observed between the Triticale lines indicating different resistance factors. One line was susceptible to all isolates, whilst another was resistant to all isolates. Isolate WBRS-74-2 was virulent on one line only. Individual plants within some of the lines often responded differently to each other.

ADULT PLANT RECEPTION NURSERIES

Samples received from cultivars to which virulence has not previously been detected cannot be tested on adult plants in either field isolation nurseries or in polythene tunnels until the following season. An early indication of increased virulence to important cultivars possessing adult plant resistance would be advantageous. Information on temperature-sensitivity has only been based on seedling test results. The effect of temperature on the expression of resistance at post-seedling growth stages remains to be determined and such information could be of value in assessing resistance relationships between cultivars, as has been done for overall resistances. Wheat 'reception nurseries' were sown at the WPBS in 1983 to monitor any increased virulence to adult plant resistances and to determine the effect of temperature on wheat:rust

interactions. Each nursery comprised 5 winter wheat cultivars sown as single plants in 5" pots. The plants were grown in a spore-proofed glasshouse and inoculated in a settling tower at the flowering stage of growth. Two replicates were incubated at a low temperature regime (10°C and 12 h photo-period) and two replicates at a high temperature regime (25°C and 16 h photo-period). Cultivars tested were:

Virtue (Adult plant resistant. Virulence previously not detected)
Hustler (" " " " " " ")
Rapier (" " " " " " ")
Avalon (Adult plant resistant. Virulence detected in 1980)
Armada (Susceptible check)

Isolates tested were cultured from samples of these same cultivars received during the 1983 field season.

Results

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

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

Origin of isolate	Test cultivar: Avalon L	Avalon H	Virtue L	Virtue H	Hustler L	Hustler H	Rapier L	Rapier H	Armada L	Armada H
WBRS-83-7 (ex Avalon)	25	30	4	25	15R	23	15R	18	30	33
WBRS-83-10 (ex Avalon)	13	20	2	13	3R	13	3R	9	15	23
WBRS-83-11 (ex Avalon)	23	30	+13MS	25	+8	20	2R	10	25	30
WBRS-83-86 (ex Rapier)	9	15	15MR	15	0	*13	8*	*9	13	14
WBRS-83-50 (ex Rapier)	25	18	10MS	5	*5	*5	20MS	*15	8	12
WBRS-83-21 (ex Hustler)	20	15	15MS	10	20MR	20	*15	*12	10	15
WBRS-83-87 (ex Virtue)	35	25	15MS	35	*20	20	*20	20	25	25
+WBRS-83-11V (ex Virtue in WBRS-83-11 test)	18	33	15MS	30	*20	*15	*17	*23	20	18
+WBRS-83-11H (ex cv. Hustler in WBRS-83-11 test)	25	33	18MR	13	30MR	35MR	2R	*25	25	35

L = Low temperature regime; H = high temperature regime;
R = resistant; MS = mixed susceptible; MR = mixed resistant;
Each value = % level of infection, mean of 2 replicates;
* = not assessed on flag leaf;
All reaction types susceptible unless indicated.

All isolates were virulent on cvs Armada and Avalon. Cvs Virtue, Hustler and Rapier responded similarly to the three isolates originating from cv. Avalon. Resistance to these was expressed at the low but not the high temperature regime. Such adult-plant, temperature-sensitive

resistance has not previously been reported. Cvs Virtue and Hustler were relatively susceptible to one of these isolates (WBRS-83-11) at the low temperature and sub-samples were taken from the respective cultivars for further tests. In these tests, the sub-culture from cv. Virtue (WBRS-83-11V) gave a similar intermediate response on cv. Virtue as the parent isolate WBRS-83-11. The sub-sample from cv. Hustler (WBRS-83-11H) gave high and similar levels of infection at both temperatures but with mixed reactions (X-type) of a generally incompatible type. A possible explanation is that these two sub-cultures are heterozygous for virulence at the locus in question which results in a stepwise progression in virulence as was postulated by Watson & Luig (1968) for Puccinia graminis tritici. One isolate from cv. Rapier (WBRS-83-50) was virulent on cv. Rapier at the low temperature but tests on cvs Virtue and Hustler were inconclusive. These difficulties arose from the devernalization of cvs Virtue, Hustler and Rapier during their culture, a problem that did not occur with the other similarly-treated cultivars and so the results should be interpreted with caution.

WHEAT BROWN RUST RESISTANCE (WBR) GROUPINGS

Diversification of winter wheat cultivars to minimise the risk of brown rust can be achieved by utilisation of information on resistance of cultivars detailed in this and previous UK CPVS reports. The groupings of cultivars given below is based on a summary of information available at the present time and may be modified in the light of future findings. Cv. Aquila is included in WBR-1 but please note above comment on its purported resistance.

WBR-factor(s)	Cultivar
WBR-1	Stetson, Hammer (Aquila)
WBR-2	Norman
WBR-5	Brigand, Galahad, Longbow
WBR-9	Avalon
WBR-x?	Mission, Fenman
WBR-y?	Virtue, Rapier, Hustler

The growing together of cultivars from within the same WBR-group carries with it a risk of cross infection. This risk can be minimised by selecting cultivars from different WBR-groups.

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BROWN RUST OF WHEAT TESTS AT NIAB

Rosemary A. Bayles and Jane E. Thomas

National Institute of Agricultural Botany, Cambridge

An isolate of Puccinia recondita (82/24) from a field crop of the cultivar Avalon, was compared in seedling and adult plant tests with three control isolates. 82/24 resembled the control Avalon - virulent isolate 80/21, confirming that this virulence is now present in the field.

Three new cultivars were included in tests and the classification of their resistances is discussed.

INTRODUCTION

The main aim of the 1983 tests was to compare a) a 1982 isolate from a field crop of Avalon (82/24) with b) the original Avalon - virulent isolate from a trial plot (80/21) and c) two control isolates (77/9 and 80/1)

METHODS

Seedlings and adult plants of 24 winter wheat cultivars were inoculated with 4 isolates of Puccinia recondita supplied by WPBS (Table 1).

Table 1

Isolates used in adult plant tests.

Code	Cultivar	Site	Region*	WBV Factors
77/9	Maris Ranger	WPBS Nursery**	W	WBV 1,2,5
80/21	Avalon	Rosemaund	WM	WBV 2,9
82/24	Avalon	Watlington, Oxon	SE	WBV 2,9
80/1	Brigand	WPBS	?	WBV 1,2,5

* = W Wales, WM West Midland, SE South East

** = Plot inoculated with isolate 76/1

All isolates originally supplied by WPBS

Seedling tests were in controlled environment chambers (16hr day at 18°C, 8hr night at 11°C). Adult plant tests were in Polythene tunnels, using the technique developed for yellow rust of wheat (Priestley and Byford, 1978). Plots were sown on 8-9 Novemb inoculated on 16 and 29 March and 21 April and assessed for percentage leaf area infection on 16 June (GS 80) and 24 June (GS 85).

RESULTS

Table 2 gives infection levels on adult plants and seedling reactions in 1983, together with corresponding results for the same isolates in 1981 and 1982.

Isolate 82/24 resembled 80/21, being virulent on Avalon and Bounty (Box D) and on the WBR 2 cultivars M.Fundin and M.Bilbo (Box C), and has therefore been classified as WBV 2,9. This result confirms that virulence for Avalon was present in the field in 1982. Evidence from NIAB variety trials in 1983 indicates that the virulence has now become widespread, since Avalon was moderately or severely infected in a high proportion of trials. It is interesting to note that Avalon has been resistant as a seedling to isolate 80/1, whereas the resistance of Bounty to this isolate is expressed only in adult plants.

1983 data confirm that Stetson resembles the WBR 1 cultivars Clement and Stuart (Box A). Hammer, in Polythene tunnel tests for the first time, appeared to fit more closely with the two cultivars Abele and Baron, which possess WBR 1, combined with an adult plant resistance overcome by 80/1 (Box B).

The interaction of adult plants of Longbow with 80/1 was also confirmed (Box E).

Cultivars classified as WBR 2 on the basis of their seedling reactions have differed markedly in their adult plant responses. M.Fundin has been susceptible to all four isolates, but M.Bilbo appears to have been relatively resistant to 80/1 and susceptible to 80/21 and 82/24. In contrast to both these cultivars, Hobbit and Norman were resistant to 80/21, but Norman differs yet again from M.Fundin and M.Bilbo in its interaction with 80/1, first noted in the 1982 Report. These results indicate a diversity of adult plant resistances operating in cultivars in the WBR 2 group.

Other cultivars in tests for the first time were Moulin and Mission. Neither showed an obvious pattern of interactions with the 4 isolates.

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

Values are mean percent leaf area infection (mean of 2 assessment dates). Data for 1980 have been omitted because of poor infection in polythene tunnels.

	Isolate	77/9			80/1			80/21		82/24
	WBV Factors	1,2,5			1,2,5+			2,9		2,9
	Year of test	81	82	83	81	82	83	82	83	83
WBR Factor	Cultivar									
WBR 1	Clement	9*	5*	18	20	6	18	0*	1	0*
	Stuart	5*	4*	13	6	3	9	0*	0*	0*
	Stetson	-	8	16	-	1	11	0*	1*	0*
	≠Aquila	3	2	14	5	4	4	0	0	0
WBR 1+	Abele	1*	0	1	8	3	10	0*	0*	0*
	Baron	0	0	1	9	16	23	0*	2*	1*
	Hammer	-	-	3	-	-	12	-	0*	0*
WBR 2	M. Fundin	11	1	17	8	3	14	27	11	20
	M. Bilbo	2	1	11	1	1	1	26	19	24
WBR 2+	Hobbit	1	0	4	4	1	3	0	0	4
	Norman	2	0	0	4	4	6	0	0	1
WBR 5	M. Huntsman	4	1	3	12	7	16	1	0	2
	Brigand	6	5	2	2	1	7	2	0	1
WBR 9	Avalon	0	0	3	0*	0*	0*	40	10	17
	Bounty	0	0	1	0	0	0	13	3	9
WBR 0+	Longbow	0	1	5	7	6	17	0	0	0
	Hustler	0	0	0	0	0	0	0	0	0
	Rapier	0	0	0	-	0	0	0	0	0
	Virtue	0	0	0	0*	0	0*	0	0	0
	Galahad	-	0	1	-	0	0*	0	0	0
	Moulin	-	-	6	-	-	0*	-	0	0
	Mission	-	-	0	-	-	3	-	2	7
	Fenman	1	1	11	4	3	8	4	5	8
	Armada	12	3	17	8	3	4	13	3	19

A, B, C, D, E

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

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

MILDEW OF BARLEY

M S Wolfe, Susan E Slater and P N Minchin

Plant Breeding Institute, Cambridge

No new or unusual pathogenicity characters or combinations were identified. There was a rapid increase in the pathogenicity for BMR 6+Ab (cv. Triumph), and a further increase in insensitivity to triazole fungicides, at least in England. Pathogenicity for BMV 3 (cv. Midas) became prevalent in England despite there being only a small area of corresponding cultivars. This change appears to have been due to the 'hitchhiking' association of BMV 3 with insensitivity to triazoles, which developed first in Scotland.

WIST data allowed an analysis of population dynamics during the season in East Anglia, which revealed a rapid increase in pathogenicity for BMV 3 and 6+Ab, and a decrease for BMV 2, 4 and 5. Changes in triazole sensitivity also varied during the season, probably dependent on the overall concentration of the fungicide at different times. There were marked differences in the pathogen populations in England and Scotland, both for pathogenicity and insensitivity, particularly later in the season. In Scotland BMV 6 and 6+Ab remain less frequent than in England, and BMV 4 and 5 more so. Insensitivity to triazoles apppears to be declining in Scotland, though not in England, but there were some initial indications of a pathogen response to the increased use of fenpropimorph in Scotland.

None of the 140 leaf samples received in 1983 were tested, principally because of laboratory test failures late in the year. This was possibly due to untraced contamination of the testing system by very low concentrations of the highly active fungicide, fenpropimorph.

No new or unusual resistance gene combinations were found from other tests. Pathogenicity for cv. Triumph was common, and pathogen genotypes able to attack cvs. Triumph and Midas, and with reduced sensitivity to triazole fungicides have become widespread in England. The association of these characters appears likely to have arisen from the increase of spores with these characters migrating from Scotland, rather than from an association of BMV 3 and BMV Ab12 (Annual Report, 1982).

Cv. Apex appears to have mlo, either alone or with, perhaps Mlg. It is more susceptible than cv. Atem, though no isolates with specific pathogenicity for it have yet been detected. This cultivar may present a degree of risk in providing a bridge for the pathogen towards the higher level of resistance of cv. Atem (mlo+Mlv).

It is evident that resistance genes from spring barley cultivars are becoming more common among winter barleys in official trials.

Survey methods

Several methods are under development for different purposes:

1) Leaf sampling: samples taken directly from plants of resistant cultivars. Most important for 'early warning' of new pathogen genotypes, and for providing the means of identifying resistance genes in new cultivars.

Table 1. Number of samples received in 1983 and the BMR group definitions of the cultivars from which they were collected

BMR group	gene	Cultivar and number of samples
0	-	Impact* (7), Maris Otter (2 fungicide treated, 5 untreated), Halcyon (4), Golden Promise (1)
1	Mlh (2 genes)	Metro* (9), Gerbel (8), Monix*(8), Fulmar*(8), Pepite* (8), Sonja (6), Igri (5), Mogador*(4), Pirate (7), Athene (2)
2	Mlg (2 genes)	Fenella (1)
3	Mla6	Carnival (2), Midas (1)
4	Mlv (2 genes)	-
5	Mla12	Medallion (4)
6	Mla7+Mlk	-
7	Mla	Delta*(1)
8	Mla9+Mlk	Leith*(-)
1+2		Panda*(10), Tipper (7)
2+4		Koru (5), Golf (2), Georgie (1)
2+5		Patty (3), Javelin* (1)
3+4		Goldmarker (3)
4+6		Klaxon* (2)
4+8		Kym (3)
6+Ab		Triumph (6), Tasman (3)
?	mlo+?	Apex (1)

*new identifications

2) Field population sampling: samples taken from plots or fields using mobile nurseries or the 'stick sampler'. In addition to the above, this provides a means of determining the structure of the population that a cultivar selects during the season, and consequently, its likely influence on other cultivars.

3) Sampling the air spora: samples obtained either from a static survey (on the Botany School roof in central Cambridge), or in the WIST. Determines the overall structure of the pathogen population in the atmosphere and may thus have some predictive value.

With sampling of the air spora, or of field populations, information can be gained directly, by assessing infection of susceptible or test cultivars, after exposure of their seedlings. Alternatively, population samples obtained on the exposed seedlings can be maintained and then tested indirectly in the laboratory on appropriate test leaf segments.

Results

Field population sampling

Values for non-corresponding pathogenicity (the level of each pathogenicity character on cultivars for which the character is unnecessary for infection) were obtained indirectly using the stick sampler at NIAB regional centres (Table 2).

The main changes in 1983 were further increases in BMV 3, 4 and 6, and a decline in BMV5. This reflects increased infection of cv. Triumph and increased insensitivity for triazole fungicides, associated with BMV 3. These changes were more marked in the air spora (Table 6).

Table 2. Values for non-corresponding pathogenicity for each of the years 1978-83

Year	BMV character 2	3	4	5	6
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
1983b	63	49	35	30	21

a - conventional survey samples
b - plot spore samples from NIAB regional centres

The pattern of values for corresponding and non-corresponding pathogenicity in the sub-populations for each BMR group are given in Table 3.

Table 3. Values for corresponding and non-corresponding pathogenicity in samples from a number of BMR group cultivars at NIAB regional centres

BMR group	BMV character 2	3	4	5	6	7	2+5	3+4	4+5	6+Ab
0	59	46	31	29	27	3	26	12	14	26
1	70	51	37	45	30	1	43	6	23	36
2	44	69	20	7	52	0	11	3	2	43
3	61	68	42	13	18	3	19	42	18	17
5	82	42	61	57	24*	5	62	18	32	27*
7	76	18	58	51	1*	41	51	12	19	1*
2+4	62	57	77	30	2*	1	23	21	21	1*
2+5	64	27	22	62	0*	0	66	25	14	0*
3+4	54	87	85	26	0*	0	14	76	15	4*
6+Ab	56	71	11*	12*	69	0	10*	4*	6*	66
means of non-corresponding pathogenicity	65	48	35	27	17	1	29	11	14	22

*consistent negative deviations

The results are similar to previous years in that, for example, BMV 4 was less frequent than expected on BMR 6 cultivars, and vice versa, and similarly for BMV 5 on BMR 6. However, from Table 3, BMV 6 and BMV 6+Ab occurred at relatively high frequencies on BMR 5, though they were absent from the populations obtained from BMR 2+5. This discrepancy occurred because the sole representative of BMR 5 was cv. Medallion, a winter barley, grown among plots of other cultivars with, mostly, still higher values for BMV 6 and 6+Ab.

In contrast with previous years, the values for BMV 6+Ab were generally higher than for BMV 6. As before, the positive association of BMV 5 and 7 was evident.

Winter barley cultivars. Large differences occurred in the frequencies of

BMV3, 5, 6 and 6+Ab on winter barleys at the NIAB regional trials, but few of the differences were consistent with previous observations. The exceptions were cv. Medallion (BMR 5) with high values for BMV 5 and relatively low for BMV 6, and cv. Athene, which gave a high value for BMV 3, associated with high values for BMV 6 and 6+Ab.

Differences among the remaining cultivars were confounded with differences between sites. For example, there was a tendency to a relatively high frequency of BMV 5 at NIAB, and a relatively high frequency of BMV 6 at Morley and Sutton Bonington.

Three of the sites were sampled both in 1982 and 1983 (Table 4). The mean values for the sites compared between years again showed the increase in BMV 3, 6 and 6+Ab between years.

Table 4. Values for non-corresponding pathogenicity at three NIAB regional centres sampled in 1982 and 1983

	BMV character								
Year	2	3	4	5	6	7	3+4	4+5	6+Ab
1982	58	27	27	36	9	1	9	26	5
1983	59	45	33	36	24	4	10	18	33

Sampling the air spora

a) Pathogenicity: indirect testing from seedlings exposed in the WIST

Samples obtained from untreated seedlings of cv. Golden Promise exposed in the WIST in 1983 in East Anglia were tested subsequently on the standard differentials (Table 5).

Table 5. Monthly changes in pathogenicity measured by indirect tests of mildew samples obtained from cv. Golden Promise seedlings exposed in the WIST

	BMV character								
Month collected	2	3	4	5	6	2+5	3+4	4+5	6+Ab
February	63	39	43	32	41	25	7	6	37
March	83	42	39	23	53	11	22	5	55
April	37	58	29	27	38	19	31	14	39
May	54	54	19	15	33	17	7	8	35
June	44	61	16	14	31	11	15	8	35
July	33	60	10	1	54	1	5	0	54
August	27	61	11	3	36	3	5	4	51

From Table 5, BMV 2, 4, 5, 2+5, 3+4 and 4+5 all tended to decline, whilst BMV 3 and 6+Ab increased with time. This was presumably a reflection of the declining contribution of winter barley to the air spora, and the increasing contributions from the large area of cv. Triumph, and the even greater area treated with triazole fungicides.

In the field, these large-scale changes were accompanied by a tendency for BMR 5 cultivars to perform well in trials. From the population shift at the end of 1983, it would seem reasonable to predict that BMR 5

cultivars should again perform relatively well in 1984.

In comparing Tables 4 and 5, the same trends are evident in relation to the increase of BMV 3 and 6+Ab, but it is also clear that the pathogen populations at the trial centres are more complex than in general agriculture, because of the continuous cultivation of a wider range of cultivars.

In July, untreated seedlings of cv. Golden Promise were exposed in northern England and Scotland. The data from indirect tests of these samples are compared in Table 6 with corresponding data from East Anglia for exposures made in June, to try to ensure similarity of crop growth stage at the time of sampling.

Table 6. Pathogenicity values in different parts of England and Scotland measured by indirect tests of mildew samples obtained from cv. Golden Promise seedlings exposed in the WIST at about the same crop growth stage

	BMV character								
Area	2	3	4	5	6	2+5	3+4	4+5	6+Ab
E. Anglia	44	61	16	14	31	11	15	8	35
N. England	55	87	34	11	11	22	9	5	4
SE Scotland	34	71	40	9	23	14	6	3	19
E. Scotland	55	36	2	40	2	25	2	1	3
NE Scotland	57	65	38	49	18	40	15	6	16

The prevalence of BMV 3 (Table 6) reflects the combined effects of the cultivation of cv. Midas in Scotland and the north, and the widespread use of triazole fungicides. The high values for BMV 6 and 6+Ab in East Anglia contrast with lower values further north, because of the greater importance of cv. Triumph in the south. The high values for BMV 5 and 2+5 in east and north Scotland may be due to the association of BMV 5 with ethirimol insensitivity, which is maintained by the relatively intensive use of ethirimol in Scotland; BMR 5 cultivars are not widely grown.

Untreated seedlings of cv. Golden Promise were exposed on the roof of the Botany School in central Cambridge at weekly intervals from late June onwards. Compared with the WIST, monthly mean 'catches' of colonies per seedling hour differed in absolute numbers (Table 7) partly because of the greater wind run over the WIST seedlings and partly because the WIST seedlings were exposed only during the diurnal peak of spore concentration in the atmosphere.

Table 7. Colonies x 10^4 per seedling per hour incubated from seedlings of cv. Golden Promise exposed in the WIST or on the roof of the Botany School, Cambridge

	Month					
Method	July	August	September	October	November	December
WIST	2583	208	125	2292	1000	0
Botany School	484	44	24	534	235	26

r = 0.99

The changes that occurred month by month (Table 7) were highly correlated and revealed a sharp peak in October, possibly due both to infections from newly emerging winter barley seedlings and to release of ascospores.

The similarity of the data obtained by the two methods is further illustrated in a comparison of pathogenicity values obtained indirectly from both sets of samples (Table 8). For both periods the data from both methods were highly correlated, though the WIST samples tended to have higher values for BMV 3, 6 and 6+Ab, while the Botany School samples had higher levels of BMV 2, 4, 5 and their combinations. This difference could have been due to the influence of NIAB and PBI trial grounds on the air spora in central Cambridge.

Table 8. Pathogenicity and triazole-insensitivity values for July/August and September/October measured by indirect tests of mildew samples obtained from cv. Golden Promise seedlings exposed in the WIST and on the roof of the Botany School, Cambridge

Time/method	ED_{50}*	BMV character 2	3	4	5	6	3+5	3+4	4+5	6+Ab
July/August										
WIST	0.080	30	61	11	2	45	2	5	2	52
Bot. School	0.083	43	56	16	7	45	8	6	5	42
Sept./Oct.										
WIST	0.058	32	60	6	3	54	3	2	2	45
Bot. School	0.053	55	75	17	9	45	7	19	2	45

*calculated on basis of g a.i. per kg seed where recommended rate = 0.375 g per kg.

b) Fungicide insensitivity: direct and indirect testing

The average level of insensitivity to triazole fungicides in the pathogen population increased in East Anglia in 1983 (Table 9).

Table 9. Insensitivity to triazole fungicides in eastern England measured directly (relative colony counts on treated exposed seedlings) or indirectly (ED_{50} samples from untreated exposed seedlings)

Method	Year 1981	1982	1983
Direct: seed trt. 0.025 g a.i.	22.6	50.8	82.6
" " 0.075 g a.i.	-	26.8	53.6
Indirect: ED_{50}	0.028	0.060	0.080

*ED_{50} for sensitive wild type =0.008

The increase was evident both from direct tests (the numbers of colonies incubated on exposed seedlings of cv. Golden Promise treated at different levels of triadimenol, relative to those on untreated seedlings) and indirect tests (the laboratory ED_{50} values for isolates obtained from untreated seedlings of cv. Golden Promise and maintained on untreated leaf segments).

Because of differences in the maintenance and exposure of seedlings in WIST surveys in East Anglia and Scotland, it was not possible to compare directly the observations in the two areas. Comparisons of indirect laboratory tests are valid (Table 10) and indicate that insensitivity hadincreased earlier in the north, because of the considerably higher values in 1981, compared with eastern England. However, by 1983, insensitivity had declined in northern England, possibly reflected by a similar change in eastern Scotland.

Table 10. Insensitivity to triazole fungicides in eastern and northern England and eastern Scotland measured by ED_{50} values from WIST samples

Area	Year 1981	1982	1983
Eastern England*	0.023	0.060	0.068
Northern England†	0.065	0.100	0.053
Eastern Scotland†	0.058	0.068	0.060

*June data †early July data

The difference between eastern Scotland and northern England in 1982 (Table 10) almost certainly relates to the decline in use of triazole fungicides in Scotland. A further difference between the two areas is the relatively greater use of fenpropimorph in Scotland than in England, which is also reflected in indirect tests made on samples collected from Scotland (Table 11).

Table 11. Relative colony numbers on leaf segments of seedlings treated with different fungicides for samples obtained in the WIST in Scotland from exposed seedlings of cv. Golden Promise untreated or treated with triadimenol or fenpropimorph

Sample source	0	Test fungicide triadimenol 1/15*	fenpropimorph 1/100	ethirimol 1/8	tridemorph 1/10
Untreated	113	46	42	29	40
Triadimenol 1/5	113	43	46	23	37
Fenpropimorph 1/100	113	28	52	14	45

*i.e. 1/15 of commercial recommended dose (equivalent to 0.025 g a.i. for triadimenol).

The data spectrum obtained from the fenpropimorph treated seedlings (Table 11) was significantly different from that obtained from untreated seedlings, and almost so in comparison with the data from the triadimenol-treated seedlings. The highest value on the fenpropimorph treated test segments was obtained from the samples from the exposed seedlings with fenpropimorph treatment. These also gave the lowest values on the ethirimol and triadimenol test segments, and the highest value on the tridemorph-treated segments, probably because of the chemical relationship of tridemorph and fenpropimorph. The diversity of mildew fungicides in Scotland and the current negative association of insensitivity characters may explain the present satisfactory performance of ethirimol in an area where insensitivity had previously been problematic.

c) Pathogenicity and insensitivity

WIST samples from England and Scotland obtained from untreated and triadimenol-treated seedlings of cv. Golden Promise were tested on standard differentials (Table 12).

Table 12. Pathogenicity of samples obtained from seedlings of cv. Golden Promise exposed in the WIST in Scotland (1983) and East Anglia (1981-83) either untreated or treated with different does of triadimenol

Source	ED_{50}	2	3	4	5	6	6+Ab	Means
1981 East Anglia								
untreated	0.028	71	14	38	39	23	7	32
triad. 0.025	0.045	53	11	24	37	33	3	27
triad. 0.125	0.085	10	12	0	18	0	0	7
1982 East Anglia								
untreated	0.060	57	41	30	43	33	35	40
triad. 0.025	0.080	44	59	47	22	22	15	35
triad. 0.075	0.093	30	50	29	17	11	13	25
1983 East Anglia								
untreated	0.080	48	52	20	18	36	38	35
triad. 0.025	0.093	41	55	27	12	34	38	35
triad. 0.075	0.108	40	63	25	14	31	34	35
1983 Scotland								
untreated	0.060	49	65	32	30	17	13	34
triad. 0.025	0.073	50	55	32	12	17	9	29
triad. 0.075	0.075	51	68	33	22	4	4	30

Pathogenicity values were generally lower in the samples from treated seedlings, but the differences decreased with time. This indicates selection for improved fitness of insensitive genotypes in the absence of fungicide. However, BMV 3 and 4 appeared less affected by association with insensitivity than did the other BMV characters, and, indeed, BMV 3 has consistently shown a positive association with triazole-insensitivity. The improvement in fitness was particularly marked for BMV 6+Ab in East Anglia, presumably because of the enormous selection imposed by the treated area of cv. Triumph.

The overall increase in BMV 3 in East Anglia apears to have been mainly due to selection for triazole insensitivity, and the association of the two characters. Although there was a consistent decrease in BMV 2, 4 and 5 overall, their values from untreated seeding samples increased as they became fitter in the absence of fungicide. This probably occurred because of increasing insensitivity on winter barley, which provides the main source of infection for the declining area of BMR 2, 4 and 5 cultivars.

In field trials at PBI in 1982/3, the influence of specific pathogenicity - insensitivity associations was evident in that cultivars with BMR 3 or 6+Ab, which tend to select for the combination BMV 3 plus 6+Ab plus triazole insensitivity, performed relatively less well with triadimenol than with ethirimol treatment. Conversely, BMR 5 cultivars, which select for the combination BMV 5 plus ethirimol insensitivity, performed less well with ethirimol than with triadimenol treatment.

MILDEW OF BARLEY IN NORTHERN IRELAND

P C Mercer

Plant Pathology Research Division, Department of Agriculture, Northern Ireland

Owing to problems of transporting samples in a viable condition all testing of pathogen virulences of barley mildew in Northern Ireland has been performed locally since 1978. The techniques employed were based on the mobile nurseries of Wolfe et al (1976) but the range of cultivars was not necessarily identical. Techniques and results for the period 1978-82 have been published separately (Mercer et al, 1984). Results for 1983 are given below.

Table 1 shows the cultivars used for examining the various virulences and Table 2 shows values for the mean pathogenicity of isolates taken from 31 crops. The most popular cultivars in Northern Ireland in 1983 were Goldmarker, Goldspear, Triumph, Midas, Golden Promise and Igri.

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

There was little change in pathogenicity values in 1983 compared with previous seasons, apart from BMV 6+Ab which increased from c 7 in 1981 to 14 in 1982 and 36 in 1983. This probably reflects the recent increase in area sown to Triumph over the past few seasons (now probably about 25%).

Table 3 shows a comparison of Northern Ireland pathogenicity values with the average values obtained by a modified mobile nursery technique at NIAB regional centres in England (Wolfe et al, 1984: Table 3). The original non-corresponding pathogenicity values for Northern Ireland are consistently higher than those from England.

Table 2 Mean pathogenicity of bulk isolates in 1983 on test range of cultivars

BMR GROUP	ISOLATE SOURCE	Number	BMV characters 2	3	4	5	6	7	8	3+4	4+5	4+6	6+Ab
0	Golden Promise	5	100	88	88	96	19	11	0	76	74	14	23
1	Igri	1	100	76	100	56	20	56	25	66	24	4	30
3	Midas	4	100	100	100	70	2	2	0	74	65	1	39
4	Varunda	2	100	69	100	18	33	0	0	60	11	23	40
2+4	Georgie	1	100	100	100	100	0	38	0	100	100	0	14
	Koru	2	76	70	100	62	18	0	0	53	56	8	22
	Golf	1	100	100	100	41	8	0	0	100	36	4	2
2+6	Mazurka	1	100	100	100	100	26	0	0	100	100	19	16
3+4	Goldspear	3	100	100	100	42	41	7	0	45	37	38	39
	Goldmarker	4	100	100	100	44	78	0	0	59	38	38	77
4+8	Kym	1	100	100	100	100	0	0	0	100	100	0	0
6+Ab	Triumph	2	100	82	100	19	60	0	0	60	13	56	65
	Tasman	1	100	100	100	38	100	24	0	70	26	100	100
2+4+5	Regent	1	100	100	100	100	4	0	0	100	100	0	4
?	Zinga	1	100	68	100	100	5	26	0	100	100	0	12
?	Candice	1	100	100	100	100	100	0	0	72	64	100	100

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

		BMV character							
		2	3	4	5	6	3+4	4+5	6+Ab
N. Ireland*	(1)	98	87	97	61	27	75	53	36
	(2)	59	53	59	37	16	45	32	22
England		65	48	35	27	17	29	14	22

* (1) = calculation of non-corresponding pathogenicity from original data

(2) = data scaled to levels of BMV 2 and 3 similar to those in England

In an attempt to make a more meaningful comparison the Northern Ireland figures were adjusted by assuming that pathogenicities for BMV 2 and 3 would be similar in all areas. Such an adjustment produces a similar range of pathogenicity values for most virulences except for the combined virulences 3+4 and 4+5 which are considerably higher in Northern Ireland.

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YELLOW RUST OF BARLEY

Rosemary A. Bayles and Jane E. Thomas.

National Institute of Agricultural Botany, Cambridge

57 samples were received during 1983. The frequency of BYV 1 remained at 100% and that of BYV 2 was 87%. Virulence for Triumph was detected in 17% of isolates.

In adult plant tests of 10 isolates, there was no evidence of cultivar x isolate interactions for winter barley cultivars. One isolate, 82/12, produced markedly higher levels of infection than other isolates on most cultivars.

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. An additional BYR factor, BYR3, has been defined as the seedling resistance possessed by the cultivar Triumph. Evidence to date suggests that this resistance is effective at the seedling stage, but not fully effective at the adult plant stage. Isolates virulent on seedlings of Triumph have yet to be tested for increased virulence at the adult plant stage.

Table 1. *Resistance factors to P. striiformis*

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

* *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 (1978).

Seedling tests with 1983 isolates

A total of 57 samples was received during 1983. Samples had been collected in a non-ramdom way from a wide range of cultivars and included 32 from

winter cultivars and 25 from spring cultivars. Isolates were made from 30 samples; the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Berac. Virulence tests were carried out for all 30 isolates.

Adult plant tests with 1982 and control isolates

Previous years' tests indicated that there were few consistent cultivar x isolate interactions in spring barley. This, together with the increased winter barley acreage and the preponderance of samples received from winter barley cultivars, led to the decision to concentrate this years' tests on winter barley cultivars and isolates.

Tests to measure the virulence of P. striiformis on adult plants of winter barley cultivars were carried out using the Polythene tunnel technique (Priestley and Byford, 1978). The same isolates and cultivars were tested in seedling tests in controlled environment chambers (16 hr day at 18°C, 8hr night at 11°C). Details of the isolates used are given in Table 2. In Polythene tunnel tests, three replicate tussocks of 24 cultivars were sown on 8-9 November, inoculated on 16 and 29 March and assessed for percentage leaf area infection on 27 April (GS 39) 6 May (GS 54) 16 May (GS 62) and 25 May (GS 64)

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

Code	Cultivar	Region *	Site	BYV Factors
Control Isolates				
74/33	Malta	N	Morpeth	BYV 1
75/101	Varunda	YL	Boroughbridge	BYV 1,2
1982 Isolates				
82/2	Igri	SW	Gloucester	BYV 1,2
82/19	M. Otter	S	Midlothian	BYV 1,2
82/13	Igri	S	Edinburgh	BYV 1,(2)
82/4	Igri	WM	Severn Stoke	BYV 1,2
82/21	Halcyon	S	Midlothian	BYV 1,2
82/12	Marko	S	Edinburgh	BYV 1,2
82/22	Medallion	S	Midlothian	BYV 1,2
82/11	Gerbel	S	Edinburgh	BYV 1,(2)

( ) = partially virulent on corresponding resistance

* = N North, YL Yorks and Lancs, SW South West, S Scotland, WM West Midlands.

RESULTS

Seedling tests with 1983 isolates

Sampling was not random and therefore the virulence frequencies for 1972-1983 (Table 3) should be interpreted with caution.

Table 3. Virulence Factor frequency (%)

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

≠ Not included in tests before 1983

The frequency of BYV 1 remained at 100%, with that of BYV 2 approaching 100%. Triumph was included in seedling differential tests for the first year and virulence was detected in 17% of isolates.

Adult plant tests with 1982 and control isolates.

Mean disease levels are given in Table 4. All cultivar/isolate combinations gave susceptible reactions in seedling tests. There was no evidence of cultivar x isolate interactions at the adult plant stage, although isolates differed in aggressiveness. Isolate 82/12 was outstanding in this respect, producing markedly higher levels of infection than other isolates on most cultivars. This may represent a general adaptation of yellow rust to winter barley cultivars which could lead to higher infection levels in the field. Isolate 82/12 will be re-tested in 1983/84.

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Table 4. Yellow rust of barley. Results of adult plant tests 1983.
Values are mean percent leaf area infection (average of 4 assessment dates)

Cultivars and isolates are listed in the order of average susceptibility and aggressiveness.

Isolate	82/4	82/19	74/33	82/2	82/21	82/13	75/101	82/22	82/11	82/12
BYV Factors	1,2	1,2	1	1,2	1,2	1,(2)	1,2	1,2	1,(2)	1,2
Cultivar										
Opera	0	0	0	0	1	1	0	0	1	2
RPB 5235/79	0	1	0	0	1	1	2	1	2	4
Libra	1	1	1	1	1	1	2	1	3	3
Selina	1	1	1	1	1	2	2	1	2	8
Igri	1	1	1	0	1	2	2	3	3	7
Medallion	2	2	2	2	3	3	2	1	3	5
Fortress	1	1	3	2	2	3	3	0	4	8
Pirate	2	1	2	3	3	4	3	3	4	9
Drummer	1	2	2	1	3	4	6	3	4	6
Pepite	0	1	3	1	3	3	4	4	4	9
Halcyon	2	1	3	3	3	4	4	4	6	6
Flamenco	1	3	4	2	5	5	5	4	5	10
Impact	1	3	3	4	1	4	6	4	6	12
Monix	2	3	6	3	4	5	4	2	8	11
Maris Otter	2	7	6	4	4	6	5	0	3	0
Gerbel	3	2	5	5	5	6	6	5	7	14
Natalie	2	2	3	8	5	7	7	9	6	12
Metro	3	5	7	5	3	7	4	6	10	14
Athene	4	6	5	4	6	6	6	9	6	11
Tipper	3	7	7	12	9	8	7	11	11	10
Panda	4	4	9	12	8	7	8	12	11	12
Astrix	4	4	9	9	10	7	10	9	12	15
Fulmar	3	4	11	8	10	9	5	10	14	15
Sonja	6	5	7	10	12	8	11	7	14	16

BYV Factors:- ( ) = partially virulent on corresponding resistance

All cultivar/isolate combinations gave susceptible reaction types (> 2.0) in seedling tests.

BROWN RUST OF BARLEY

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

Welsh Plant Breeding Station, Aberystwyth

Seedling tests of 21 isolates of Puccinia hordei Otth. allowed identification of two virulence patterns. All three isolates of octal designation 653 carried additional virulence to cvs Triumph and Carnival, as did 11 of the isolates of octal race 673. Tests of adult plants with two selected pathogen isolates were carried out in field nurseries. Cultivar Medallion was the only winter cv. to express resistance to octal race 653 which was virulent on cvs Triumph and Carnival in seedling tests. Cultivar Triumph was susceptible in this nursery, but cv. Carnival which has a similar response in the seedling stage was relatively resistant suggesting that it has additional adult plant resistance.

GLASSHOUSE SEEDLING TESTS WITH 1983 ISOLATES

Seventeen of the 25 samples of barley brown rust received were from the east of England, with approximately a third originating from spring cultivars. The 21 isolates successfully cultured were tested on the standard set of nine differential cultivars. These carry different identified Pa genes for reaction to P.hordei (Jones & Clifford, 1980). In addition, cvs Triumph and Carnival were included in all tests.

Results

The tests identified two virulence combinations based on the reactions with the standard differential cultivars. The most common (18 isolates) was combination octal 673 which is avirulent only on Pa_3 and Pa_7 carriers. The other combination, octal 653, differs in lacking virulence on Quinn (Pa_2 + Pa_5) and occurred in three isolates. This virulence combination was first detected in 1982. All isolates of race 653 and 11 isolates of race 673 were fully compatible with cvs Triumph and Carnival. Virulence to cvs Triumph and Carnival in combination with octal race 673 had not previously been detected.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Four replicates of seventeen winter cultivars were sown in each of two standard isolation nurseries in the autumn of 1982. In the following spring, seventeen spring cultivars were also sown, with four replicates in the nursery to be inoculated with isolate BRS-82-22 (octal race 653 virulent on cvs Triumph and Carnival), and two in the nursery inoculated with the simple octal race 11. A mixture of the cvs Gerbel and Pirate was used as a spreader for the winter cultivars and cv. Midas for the spring entries. Two assessments of disease development were made.

Results

A good level of infection developed throughout the nursery inoculated with isolate BRS-82-22 (Table 1). Octal race 11 failed to infect the winter spreaders to a significant level and this was probably a reflection of the relatively resistant reaction of cvs Gerbel and Pirate and the test cultivars to this race compared with the more widely virulent race 653. The susceptible spring cultivars became heavily infected which allowed comparisons to be made between cultivars and isolates. Cultivar Medallion was the only winter cultivar to express resistance to octal race 653, whilst cvs Monix and Fenella appeared less susceptible than the remainder. In the spring entries, cv. Simon (Pa_3) was resistant to both isolates, although some compatibility was observed in the nursery inoculated with octal race 11. This suggests that this nursery had been contaminated with a Pa_3-virulent race, thus the results should be interpreted with caution. The responses of cvs Triumph and Carnival to isolate BRS-82-22 in the previous year's seedling tests were similar. In these field tests, however, cv. Triumph was susceptible to this isolate, but cv. Carnival was relatively resistant. This suggests that it may have additional adult plant resistance.

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Table 1. Percent infection in barley brown rust isolation nurseries - WPBS 1983

Cultivar	Octal race 653 + TC %*	Octal race 653 + TC RT+	Octal race 11 %*	Octal race 11 RT+
Winter				
Medallion	5	R	1	MR
Monix	8	S	1	S
Fenella	12	S	2	S
Fulmar	17	S	5	S
Athene	20	S	2	S
Pirate	20	S	3	S
Metro	21	S	2	S
Panda	20	S	3	S
Tipper	23	S	2	S
Otter	24	S	4	S
Sonja	25	S	5	S
Vixen	25	S	2	S
Impact	25	S	3	S
Pipkin	28	S	2	S
Pepite	30	S	5	S
Igri	31	S	4	S
Gerbel	33	S	3	S
Spring				
Simon	Trace	R	2	MR
Triumph	22	S	10	MR
Patty	11	MR	9	MR
Carnival	12	MR	6	MR
Apex	12	MR	9	MR
Tasman	14	MR	5	MR
Vada	12	MR	14	MS
FD 0400/23/4	10	MR	11	MR
Armelle	13	MS	6	MS
Klaxon	14	S	9	MR
Egmont	15	MS	10	MR
Delta	16	S	9	MR
Golf	17	S	15	MS
Kym	18	MS	19	MS
Atem	20	MS	10	MS
Koru	19	S	14	MS
Midas	33	S	34	S

*Mean of 4 replicates at 2 assessment dates (except octal race 11 on spring cvs = 2 reps)

+R = Resistant, MR = Moderately resistant, MS = Moderately susceptible, S = Susceptible

RHYNCHOSPORIUM OF BARLEY

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

Welsh Plant Breeding Station, Aberystwyth

Seedling tests of 50 Rhynchosporium secalis isolates allowed identification of pathogen virulence factors. One new virulence factor, BRV-5, was identified. This is the first time that virulence to BRR-5 at the seedling stage, carried by cv. La Mesita, has been detected in the UK. In a supplementary seedling test, the resistance of cv. Osiris only was effective against an isolate carrying BRV-5. Previous isolate:cultivar interactions had suggested that cvs. Gerbel and Tipper carried the cv. Astrix resistance (BRR-2) but ten isolates from the 1983 survey were virulent on cv. Astrix and avirulent on cvs Gerbel and Tipper. In field isolation nurseries cvs Gerbel and Tipper responded similarly, confirming the results of the seedling tests. Cv. Fenella was highly susceptible to race UK 1, thus conflicting with the previous year's results when it was resistant to the same isolate. This may have been due to non-authentic seed. Within the spring cultivars, Armelle and Koru responded similarly suggesting a common resistance (BRR-1). The resistance of La Mesita was confirmed to be ineffective at the adult plant stage.

SEEDLING TESTS WITH 1983 ISOLATES

A total of 74 samples of barley scald was received. Of these, 47 originated from winter cultivars, and 27 from spring cultivars. The geographic origin of the samples was widespread. Isolates of Rhynchosporium secalis were successfully cultured from 50 of these samples and tested on the standard set of differential cultivars and additional winter cultivars. The seedling test procedures were those described previously (Jones & Clifford, 1979) and assessments were made of percentage infection and reaction type (Ali & Boyd, 1974). Test cultivars and their resistance factors are given below.

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

Results

The virulence factors identified in the 1983 isolates, numbers of isolates and their corresponding UK race designations are given in Table 1.

Table 1. Virulence factor combinations (races) identified from the 1983 survey

Number of isolates	Virulence (BRV) factor(s)	Race
3	BRV-0	UK 1
0	BRV-1,2,3	UK 2
4	BRV-3	UK 3
0	BRV-1,3	UK 4
23	BRV-1,2,3,4	UK 5
19	BRV-3,4	UK 6
1	BRV-5	UK 7

One new race, designated race UK 7, was identified. This race, isolated from a plot of cv. Pipkin at WPBS, overcame the resistance of the differential cv. La Mesita (BRR-5). Virulence to La Mesita at the seedling stage has not previously been detected in the UK. This isolate, RS-83-14, was avirulent on the remainder of the differential cvs, excluding cv. Maris Mink (BRR-0). A number of cultivars thought to carry BRR-5 were inoculated at the seedling stage with this isolate. Cv. Maris Mink was also included as a susceptible check. The results are given in Table 2.

Table 2. Standard test with isolate RS-83-14 of seedling plants thought to carry the Rh^4 resistance gene

Cultivar	Level of infection*
Maris Mink	10
Pipkin	10
Magnum	10
Osiris	3
La Mesita	10
Corgi	10
WPBS Breeding Line	8
" " "	8

*0 (completely resistant) to 10 (highly susceptible)

Only cv. Osiris showed a low level of infection, which suggests that it has resistance not present in the other cultivars.

Ten isolates were identified which were virulent on cv. Astrix but avirulent on cvs Gerbel and Tipper. Previous isolate:cultivar interactions had suggested that these two cultivars carried the cv. Astrix (BRR-2) resistance (Jones & Clifford, 1983).

With the increasing number of agriculturally-relevant virulence combinations now being identified, the shortcomings of arbitrarily assigning UK race numbers to isolates carrying particular virulences become more apparent.

Various systems of nomenclature have been proposed, but the most succinct, informative and logical one appears to be the octal/binary system proposed by Gilmour (1973). The adoption of such a system for Rhynchosporium secalis:Hordeum vulgare would result in the following designations.

Differential cultivars in fixed linear order

Current race no.	Osiris BRR-6	La Mesita BRR-5	Igri BRR-4	Athene BRR-3	Astrix BRR-2	Armelle BRR-1	Octal virulence designation
UK-1	0+	0	0	0	0	0	0
-3	0	0	0	1	0	0	4
-4	0	0	0	1	0	1	5
-2	0	0	0	1	1	1	7
-6	0	0	1	1	0	0	14
-5	0	0	1	1	1	1	17
-7	0	1	0	0	0	0	20

+0 = Resistant, 1 = Susceptible

ADULT PLANT TESTS IN FIELD NURSERIES

Two nurseries, comprising 19 winter and 18 spring cultivars, were sown in the 1982-83 season using standard procedures. The nurseries were inoculated with one or other of the following isolates.

UKCPV Survey Code	Virulence characteristics
RS-82-26	BRV-1,2,3,4 (Race UK 5)
RS-81-77	BRV-0 (Race UK 1)

Results

Disease assessments were made on the flag leaf, flag leaf minus one, and flag leaf minus two. The results are summarised in Table 3. High levels of infection were achieved on the susceptible cultivars in both nurseries. The results of infection on the winter barleys showed that cv. Hoppel again expressed its high level of resistance. Cvs. Gerbel and Tipper, which express the same pattern of response at the seedling stage, showed very similar disease levels. In contrast with the previous year's results cv. Fenella was highly susceptible to isolate RS-81-77. Within the spring cultivars, Armelle was resistant in both nurseries although it is highly susceptible to Race UK 5 (BRV-1,2,3,4) at the seedling stage under glasshouse conditions. Cv. Koru, which carries the same resistance (BRR-1) as cv. Armelle, was also resistant to isolate RS-81-77, but was more susceptible to isolate RS-82-26 than cv. Armelle. Both isolates were virulent on the upper leaves of cv. La Mesita confirming previous observations, but cv. Corgi which carries the same resistance gene (Rh^4) was more resistant, particularly to race UK 5 (BRV-1,2,3,4). Cv. Proctor was less infected by this isolate than the remainder of the spring cultivars.

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Table 3. Percent infection in Rhynchosporium isolation nuseries 1983

Cultivar	Isolate RS-82-26 (UK5)				Isolate RS-81-77 (UK1)			
	F	F-1	F-2	$\bar{x}$	F	F-1	F-2	$\bar{x}$
Winter								
Hoppel	11	12	11	11	3	3	3	3
Metro	14	10	8	11	2	1	0	1
Pipkin	10	16	17	14	4	12	13	10
Monix	15	13	12	13	11	11	11	11
Astrix	14	15	15	15	3	7	11	7
Pirate	15	20	18	18	3	5	6	5
Igri	18	21	18	19	5	12	14	10
Athene	16	28	33	26	6	15	24	15
Gerbel	20	23	27	23	5	11	12	9
Tipper	23	25	20	23	10	12	15	12
Pepite	22	24	21	22	12	15	13	13
Sonja	27	25	26	26	10	12	14	12
Fulmar	37	37	27	34	14	25	23	21
Panda	40	27	22	30	26	21	18	22
Impact	45	44	35	41	13	16	13	14
Medallion	50	52	57	53	24	28	21	24
Maris Otter	48	58	73	60	40	54	69	55
20201 Co (Vixen)	61	67	70	66	33	38	48	40
Fenella	59	62	68	63	55	56	56	56
Spring								
Armelle	2	7	9	6	2	3	5	3
Koru	12	19	17	16	1	5	6	4
Proctor	1	3	7	4	15	29	25	23
Corgi	1	2	4	2	8	13	15	12
La Mesita	34	15	11	20	39	22	12	24
Atem	4	14	15	11	27	36	36	32
Egmont	8	18	17	14	19	26	24	23
Kym	7	22	17	15	18	31	27	25
Triumph	13	23	19	18	35	35	34	35
Rhapsody	3	15	21	13	40	47	36	41
Goldmarker	5	17	20	14	39	46	39	41
Doublet	6	21	21	16	29	44	40	38
Klaxon	10	25	21	19	28	32	29	30
Delta	14	26	19	20	34	39	25	33
Patty	8	20	19	16	48	49	47	48
Carnival	8	23	26	19	31	63	47	47
Apex	12	26	25	21	30	40	38	36
FD 0400/23/4	8	23	27	19	47	28	53	41

F = Flag leaf; F-1 = Flag leaf minus 1; F-2 = Flag leaf minus 2
$\bar{x}$ = of 4 reps, 2 scoring dates

NET BLOTCH OF BARLEY

B.C. Clifford, R. Del Buono & E.R.L. Jones

Welsh Plant Breeding Station, Aberystwyth

All except one of the 31 net blotch samples received were from winter barley cultivars. Within the differential cultivars, virulence corresponding to C.I. 9214, C.I. 739, Proctor, Code 65, C.I. 9518 and Tenn. 61-119 was detected. The additional winter barleys which have current relevance to UK farming were tested and all had high frequencies of virulence. Virulences occurred in various combinations, the simpler combinations being the more frequent. An isolate from cv. Kym grown in Fife, Scotland displayed distinctive spotting lesions although some differential cultivars were more severely affected than others. The isolate was morphologically similar to Pyrenophora teres. Isolation nurseries were sown in the 1982-83 season. Of the two isolates tested, the more widely virulent one (BNS-82-5) as determined by glasshouse seedling tests, gave higher levels of infection on cvs. Athene, Pirate, Fenella, Monix, Triumph and Klaxon than did the simpler isolate BNS-82-38. Both winter and spring cultivars displayed a range of responses from highly susceptible to resistant.

GLASSHOUSE SEEDLING TESTS WITH 1983 ISOLATES

A total of 31 samples of net blotch was received during 1983. This represented a large decrease from the 209 samples received in the previous year. All samples, except one, were from winter cultivars, and were of widespread origin (Table 1).

Table 1. Origin of samples of barley net blotch received in 1983

Location (ADAS Region)	No. of samples	Winter cultivar	No. of samples	Spring cultivar	No. of samples
East	14	Sonja	5	Kym	1
East Central	8	Athene	3		
South	5	Igri	3		
South West	2	Fulmar	3		
West Central	1	Otter	2		
Scotland	1	Gerbel	2		
		Pirate	2		
		Pepite	2		
		Halcyon	2		
		Tipper	2		
		Video	1		
		Metro	1		
		Panda	1		
		Monix	1		
Total	31		30		1

The isolates of Pyrenophora teres Drechs. successfully cultured were inoculated onto seedlings of 13 differential cultivars (Table 2) plus 16 additional winter cultivars, using procedures described previously (Clifford & Jones, 1981).

Table 2. Differential cultivars used for isolate testing

Code number	Cultivar	Type
1	C.I. 5401	Spring
2	C.I. 6311	Spring
3	C.I. 9820	Spring
4	C.I. 739	Spring
5	C.I. 1243	Spring
6	C.I. 4795	Spring
7	C.I. 4502	Spring
8	C.I. 4979	Spring
9	Proctor	Spring
10	Code 65	Winter
11	C.I. 9518	Winter
12	Tenn. 61-119	Winter
13	C.I. 9214	Spring

Responses of the cultivars to inoculation with the isolates were classified into reaction types (Clifford & Jones, 1981).

Results

Viable cultures were made from 21 of the samples. All of the isolates were from barley cultivars grown in the 1982-83 season. The frequencies of virulence to each of the differential cultivars for the last four years are given in Table 3 but because of the low number of isolates

Table 3. Frequencies of virulences corresponding to each differential cultivar (1980, 1981, 1982 and 1983 survey)

		Virulence frequency (%)			
Code number	Cultivar	1983	1982	1981	1980
1	C.I. 5401	0	8	0	4
2	C.I. 6311	0	20	0	4
3	C.I. 9820	0	6	0	11
4	C.I. 739	24	39	0	0
5	C.I. 1243	0	27	0	11
6	C.I. 4795	0	22	0	18
7	C.I. 4502	0	9	0	18
8	C.I. 4979	0	31	0	37
9	Proctor	52	-	-	81
10	Code 65	19	16	0	26
11	C.I. 9518	90	88	66	96
12	Tenn. 61-119	19	55	71	55
13	C.I. 9214	9	11	-	-

tested, the results for 1983 should be interpreted with caution. Of the three winter lines, C.I. 9518 was again susceptible to a large number of the isolates, virulence to Tenn. 61-119 occurred at a lower frequency than in previous years, and Code 65 was resistant to the majority of isolates tested, in common with previous results.

Six of the spring cultivars were completely resistant to all isolates. Cv. Proctor, which was not included in the 1981 and 1982 tests, was susceptible to about half of the isolates. A low frequency of virulence was observed on C.I. 9214, which corresponded with the 1982 results when this cultivar was first included. Virulences occurred in various combinations in the different isolates (Table 4) ranging from the simple common combination of virulences 9 and 11, to the more complex and infrequent 4, 9, 10, 11, 12. The frequency of virulence to the winter cultivars of current relevance to UK farming was very high.

Table 4. Virulence combinations and their frequencies (1983 isolates)

Virulence combination	Number of isolates
0	1
11	5
12	1
9,11	4
10,11	2
11,13	1
4,9,11	3
9,11,12	1
2,9,10,11	1
4,9,10,11	1
4,9,10,11,12	1

A conidiospore dose: host response study has shown that inoculum dose considerably affects the outcome of infection in terms of symptom expression. Below a certain spore concentration (approx. 5×10^4 spores/ml) there is a shift to reduced symptom expression even in susceptible cultivars.

One sample (BNS-83-31) from cv. Kym grown in Fife, Scotland displayed unusual spotting symptoms. The lesions varied from small (1 mm) round spots to larger (10 mm) elliptical brown lesions some of which merged to form irregular blotches. Following standard procedures for P.teres, a fungal isolate was obtained and inoculated on to the differential cultivars. All cultivars showed spotting symptoms but some, such as cvs Pipkin, Tipper, Gerbel, Medallion, C.I. 9518 and Proctor were more severely affected and on those, lesions merged to give short 'drumstick' or striping lesions up to 3 mm in length. Small (1 mm) round spots were produced on other cultivars. Isolation from cv. Pipkin and re-inoculation of the test cultivars gave a similar pattern of results. No netting symptoms, normally associated with P.teres, were observed.

Preliminary comparisons between the isolate from cv. Kym and 'normal' netting forms of P.teres indicate that:

1) Growth in culture on lima bean agar is similar although the'spotting' culture was more adpressed and showed less mycelial growth; the dark concentric ring development, reflecting circadian rhythm under NUV light, was thus more apparent.

2) Conidiospore morphology is similar in both forms. In the spotting form, spores were large, cylindrical with rounded ends, 2-6 septate with slight constrictions at the septa. Spore sizes were 60.4 x 17.6 µm (range 35.7 - 92.8 x 9.5 - 26.2 µm) for the spotting form compared with 80.9 x 22.4 µm (range 59.5 - 114.2 x 16.7 - 28.6 µm) for the netting form. Both fall within the range reported for P.teres (Jones & Clifford, 1983) and it would appear that the spotting isolate conforms with the description of P.teres Drechs. f. maculata Smedeg. reported by Smedegaard-Petersen (1971).

FIELD ISOLATION NURSERIES WITH 1982 ISOLATES

Some cultivars are reported to show high levels of resistance in the field. Maris Otter, Pirate and Tipper have NIAB ratings of 8, 7 and 7 respectively (Anon, 1984). To determine whether virulence to these cultivars is becoming more widespread and to gain information on whether the field response corresponds to that of seedlings tested in the glasshouse, isolation nurseries were sown in the 1982-83 season. Seventeen spring and sixteen winter cultivars were sown as 30 cm^2 clumps spaced 70 cm apart in each direction. Cultivars were replicated within each nursery, and a susceptible spreader cultivar was sown between each row of test cultivars. A mixture of cvs Hoppel, Athene and Sonja was used as a spreader between the winter-sown clumps, and a susceptible spring barley breeding line was sown between the spring-sown cultivars. Inoculation of the nurseries was carried out by spraying spore suspensions several times during the season. The nurseries were inoculated with one or the other of the following isolates, obtained from the 1982 survey.

Survey code	Virulence combination
BNS-82-5	2, 4, 5, 6, 8, 10, 11, 12
BNS-82-38	4, 11, 12

Results

The cultivars were assessed on the percentage leaf area infected on several occasions. Disease symptoms were slow to develop, but susceptible cultivars eventually developed reasonable levels of infection. Because of this slow development, only the final disease assessment is reported (Table 5). Levels of infection were generally higher in the nursery inoculated with the more widely virulent isolate BNS-82-5. Winter and spring cultivars are listed in order of decreasing mean susceptibility in the nurseries in Table 5. The cultivars showed a similar order of responses to the individual isolates but there were exceptions to this, notably with cv. Athene which was highly susceptible to isolate BNS-82-5 but which showed much lower levels of infection to isolate BNS-82-38. Cvs Pirate, Fenella and Monix were also more compatible with the widely virulent isolate. Similar specific interactions with particular isolates collected either in spring or autumn 1982 were observed and reported in the 1982 UK CPVS report

Table 5. Percent infection in net blotch isolation nurseries - WPBS 1983

	BNS-82-5	BNS-82-38	$\bar{x}$ of 2 nurseries
Winter cultivars			
Sonja	44*	27	36
Pepite	23	18	21
Athene	31	9	20
Panda	21	16	19
Igri	20	13	17
Impact	16	15	16
Pirate	19	8	14
Maris Otter	14	13	14
20201 Co (Vixen)	15	10	13
Medallion	10	16	13
Fenella	17	6	12
Pipkin	15	8	12
Metro	11	10	11
Monix	15	3	9
Tipper	10	8	9
Gerbel	8	6	7
Spring cultivars			
Carnival	23	18	21
Tasman	23	18	21
FD 0400/23/4	16	13	15
Triumph	18	8	13
Athos	9	10	10
Klaxon	13	4	9
Kym	10	5	8
Goldmarker	9	6	8
Apex	9	7	8
Midas	7	6	7
Delta	9	4	7
Koru	6	3	5
Patty	6	3	5
Egmont	5	4	5
Georgie	6	4	5
Atem	5	3	4
Golf	5	2	4

*% Leaf area infected

BNS-82-5 Mean of 4 replicates

BNS-82-38 Mean of 4 replicates (winter cultivars)
Mean of 3 replicates (spring cultivars)

(Clifford & Jones, 1983) for both cvs Athene and Pirate. Cv. Sonja was highly susceptible to both isolates, confirming its NIAB rating of 3. Within the spring cultivars, Triumph and Klaxon appeared to differentiate the isolates, although both cv. Tasman and cv. Carnival which have cv. Triumph as a parent were highly susceptible to both isolates. A wide range of susceptibility was observed in both the winter and spring cultivars.

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MILDEW OF OATS

I.T. Jones & E.R.L. Jones

Welsh Plant Breeding Station, Aberystwyth

In a year of low mildew incidence only twenty-two samples were received, and the thirteen isolates successfully cultured were all from West Wales.

The new spring oat cultivar Avalanche was assigned to OMR group 3 and the winter oat Bulwark to OMR 1.

The most prevalent and most complex virulence combination OMV 1,2,3 (Race 5) in 1982 was drastically reduced in 1983 to 8% frequency of samples, the simpler OMV 1,2 (Race 3) combination replacing it with a frequency of 77%, possibly due to very little area allocated to growing OMR 3 cultivars.

No virulence was found to the Avena barbata resistance factor OMR 4 in 1983.

Experiments to detect any adaptation in the mildew isolates to adult plant resistance were carried out using inoculum increased in isolation for several generations. However, more replication of leaf segments was used than in the previous season. There was some indication of adaptation to the Milo resistance but this was not conclusive, and requires further monitoring. Rhiannon showed very high resistance in all tests, even in the presence of corresponding virulence to its overall specific factor (OMR 3).

SEEDLING TESTS WITH 1983 ISOLATES

Only twenty-two leaf samples were received in 1983, probably due to the generally low incidence of mildew. Several NIAB trials officers had reported that oat mildew had not been seen on their trials during 1983.

Of the seven samples received from England, one was from the East, two from the East Central, three from the West Central and one from the South Regions. The remaining fifteen samples were obtained from West Wales, and all thirteen samples successfully cultured were from this area.

The methods used to culture and test the mildew isolates were as described previously (Jones & Jones, 1980) and their individual virulence factors (OMV) were assigned according to the reaction of the differential cultivars Milford, Manod, Cc 4146, 9065 Cn 6/3/74 and Cc 6490.

Results and Discussion

The resistance grouping of the spring oat cultivar Avalanche (Ben 6229), provisionally recommended by NIAB for 1984, has been determined as OMR 3, and that of the winter oat Bulwark as OMR 1, the latter cultivar also provisionally recommended for 1984. The resistance groupings of all recommended spring and winter oats for 1984 are given in Table 1.

Table 2 gives the details of the mildew samples tested, and in Table 3 the virulence frequencies in 1983 are compared with those of the previous three years.

Table 1. Resistance grouping of cultivars on 1984 NIAB Recommended List

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

* = New recommendation; (W) = winter oat

Table 2. Locations from which mildew samples were received, the cultivars concerned, and the virulences identified for each sample

Location	Cultivars	Virulences (OMV)
WALES		
NIAB Trials	Dula	1 + 2
Trawscoed, Dyfed	Matra	1 + 2
	Cabana	1 + 2
WPBS Aberystwyth, Dyfed	Bulwark	1 + 2
	07198 Cn I/3/2	1 + 2
	07171 Cn I/17/1	1 + 2
	06764 Cn	1
	76-17 Cn	1
	E 2301	1 + 2 + 3
Morfa Mawr (WPBS)	Leanda	1 + 2
Llannon, Dyfed	Dula	1 + 2
	Perona	1 + 2
	Saladin	1 + 2

In contrast to the results of the previous year, the most frequent virulence combination in 1983 was OMV 1 + 2 (race 3), the most prevalent and complex OMV 1 + 2 + 3 (race 5) in 1982 (43%) being reduced to a low frequency of 8% or one sample in 1983. These fluctuations, however, must be viewed with caution due to the low number and the restricted area from which samples were received in this season, and the change may not be a real effect.

Two samples from advanced breeding lines 06764 Cn and 76-17 Cn (Tables 2 and 3) were classified (Jones & Jones, 1979) as having only OMV 1 on the basis that they gave resistant reactions on 9065 Cn 6/3/74 (1-2 reaction

Table 3. Virulence group frequencies identified from samples received in 1983 compared with previous three years

Virulence group (race)	No. of isolates in 1983	Frequency (% total) 1983	1982	1981	1980
OMV 1 (2)	2*	15	0	0	0
OMV 1 + 2 (3)	10	77	39	68	51
OMV 1 + 3 (4)	0	0	4	0	3
OMV 1 + 2 + 3 (5)	1	8	43	32	41
OMV 1 + 2 + 4 (6)	0	0	0	0	3
OMV 1 + 2 + 3 + 4 (7)	0	0	14	0	2
Number of isolates tested	13	13	28	47	63

*These two isolates classified as OMV 1 because not compatible on 9065 Cn 6/3/74 and not completely compatible on the differential cultivar Cc 4146 although attacking cultivars with resistance derived from Cc 4146 - see also text

type) and Cc 4146 (On-2). All mildew cultures were also tested on cultivars with resistance derived from Cc 4146, namely, 07718 Cn, Margam, Maris Tabard, Maris Oberon and Trafalgar. These cultivars were all completely susceptible (Type 4 reaction) to the two cultures, indicating that Cc 4146 probably has more than one gene for resistance and that the whole complement has not been transferred to the bred lines.

In contrast to the previous year when virulence to the A.barbata (OMR 4) resistance was definitely detected in one sample, and partial virulence in another three samples (Jones & Jones, 1983) none was found in the 1983 season, suggesting that its occurrence is still at a very low frequency.

ADULT PLANT TESTS

Tests were carried out, as in 1982, to investigate whether adaptation to adult plant resistance was occurring in the mildew population produced on certain cultivars. The incidence of mildew was very low or non-existent on large multiplication plots of certain cultivars e.g. Milo and Rhiannon. Mildew sampling using the Schwarzbach spore-trap had, therefore, to be carried out on these cultivars grown in a small plot trial. Inter-plot contamination and low levels of infection, however, made the results very unreliable. Consequently, mildewed leaves from cultivars, Mostyn, Milo, Orlando, Trafalgar and Cabana were collected and the cultures multiplied on the respective hosts for five generations in spore-proof glasshouse sections or modules.

Plants of the Test cultivars Selma, Mostyn, Milo, Rhiannon, Orlando, Trafalgar and Cabana were grown mildew-free in a spore-proof glasshouse in natural daylight with 9 h supplementary lighting during the night. Details of five of the test cultivars are given in Jones & Jones (1983). Two new cultivars were added in the tests reported here, namely, Rhiannon and Cabana. Rhiannon is a huskless or naked oat bred at WPBS and at present in National Trials, and possesses the same overall mildew resistance (OMR 3) as in Mostyn and Milo. Cabana, bred by Nickerson R.P.B. Ltd. and placed on NIAB Recommended List in 1982 has the same overall resistance factor (OMR 2) as in Trafalgar and Orlando.

In February 1984, 2.5 cm long leaf segments were cut from the uppermost fully expanded leaf 6 (lowermost leaf = 1) (G.S. 16) of each of the seven cultivars and placed on water agar (5 g/l) with 150 mg/l benzimidazole contained in polystyrene boxes (103 x 103 x 20 mm). Each box contained 14 segments i.e. the seven test cultivars arranged randomly in two blocks. For each inoculation two of these boxes were used in turn, thus making a total of four blocks for any one test. For an inoculation, a box containing the detached leaf segments was fitted to the base of the Schwarzbach spore-trap and collection proceeded for 30 secs, the diseased plants in a module being shaken to release spores at the time of spore collection. This test is referred to as Test 1.

The same procedure was repeated for a later test (Test 2) carried out in March when plants were beginning to show panicle emergence (G.S. 50) the segments being now taken from the leaf below the flag leaf (Flag-1). Spore collection time for this test was reduced from 30 to 15 secs as the previous test had shown very high infection levels.

In both tests the inoculated leaf segments were incubated under a controlled environment of 10 ± 2°C and 12 h photoperiod, and after eight days the percentage leaf segment area showing mildew infection was assessed.

Results and Discussion

In order to ascertain the virulence spectrum of the individual mildew cultures, seedlings of the standard set of differential varieties were inoculated, and the reaction type recorded on a 0 (resistant) to 4 (susceptible) scale. The virulences detected on each culture were as follows:

Table 4. Oat mildew virulence (OMV) identified in the five mildew cultures

Mildew culture and inoculum source	Oat mildew resistance group	Oat mildew virulences identified
Mostyn	OMR 3	OMV 1 + 2 + 3
Milo	OMR 3	OMV 1 + 2 + 3
Cabana	OMR 2	OMV 1 + 2
Trafalgar	OMR 2	OMV 1 + 2
Orlando	OMR 2	OMV 1 + 2 + 3

From the technical aspect Test 1 was more precise than Test 2, the coefficient of variation (CV) for the untransformed data being 21% for Test 1 compared with 30% for Test 2. For the logit transformed data, the CV's were similar at 18.1% and 18.4% respectively, a considerable improvement from the previous year's value of 28%. However, these tests were carried out under glasshouse and not field conditions. Another indication of the reliability of the method was given by the fact that differences between blocks, boxes and their interaction in the untransformed data were not significant in Test 1. However, in Test 2 there was a highly significant difference between blocks, but differences

between boxes were not significant. Logit transformation did not alter the significance of the block differences.

The percentage leaf segment area covered with mildew for Test 1 is presented in Table 5, and the means after analysis of the logit transformation of the original values are given in Table 6. The corresponding presentations for Test 2 are given in Table 7 and 8 respectively. All LSD are at P = 0.05 level unless otherwise stated.

Table 5. Percentage leaf segment area infected with mildew using detached segments of leaf 6 (Test 1) (means of two blocks, two boxes and three recorders)

Test cultivars		Inoculum source: Mostyn (OMR 3)	Milo (OMR 3)	Cabana (OMR 2)	Trafalgar (OMR 2)	Orlando (OMR 2)	Mean
Selma	(OMR 0)	36.2	41.7	30.8	37.5	30.8	35.42
Mostyn	(OMR 3)	26.7	38.8	9.3	0.6	36.7	22.40
Milo	(OMR 3)	31.7	40.0	2.2	0.1	47.5	24.29
Rhiannon	(OMR 3)	0.3	0.2	0.3	0.5	0.8	0.42
Cabana	(OMR 2)	52.9	54.2	44.2	65.8	44.2	52.25
Trafalgar	(OMR 2)	36.3	18.8	29.2	30.0	30.0	28.85
Orlando	(OMR 2)	2.4	2.9	3.8	10.7	10.1	5.98
Mean		26.66	28.06	17.12	20.74	28.57	

Table 6. Mean percentage leaf segment area infected +1.0 (Test 1) (logit transformation)

Test cultivars		Inoculum source: Mostyn (OMR 3)	Milo (OMR 3)	Cabana (OMR 2)	Trafalgar (OMR 2)	Orlando (OMR 2)	Mean (LSD=±0.0566)
Selma	(OMR 0)	-0.2627	-0.1511	-0.3933	-0.2462	-0.4066	-0.2920
Mostyn	(OMR 3)	-0.4947	-0.2124	-1.1008	-2.1044	-0.2799	-0.8384
Milo	(OMR 3)	-0.3796	-0.1923	-1.7936	-2.2683	-0.0328	-0.9333
Rhiannon	(OMR 3)	-2.1874	-2.2509	-2.1754	-2.1626	-2.1324	-2.1818
Cabana	(OMR 2)	0.0797	0.1102	-0.0981	0.3704	-0.1038	-0.0717
Trafalgar	(OMR 2)	-0.2689	-0.7410	-0.4768	-0.4064	-0.4109	-0.4608
Orlando	(OMR 2)	-1.7998	-1.7370	-1.6664	-1.0990	-1.1589	-1.4922
Mean (LSD=±0.0478)		-0.7591	-0.7392	-1.1006	-1.1309	-0.6465	-0.8753

LSD to compare inoculum source/test cultivar means = ±0.1265 (P = 0.05) and ±0.2123 (P = 0.001)

The cultivar Selma was chosen as a highly susceptible OMR 0 cultivar. However, in these tests it has not proved the most susceptible, and its complete lack of infection in Test 2 when inoculated with Milo inoculum cannot be explained.

An outstanding feature of these results is the consistently high level of resistance shown by the test cultivar Rhiannon to all isolates including those possessing virulence (Table 4) to its major gene resistance OMR 3 i.e. inoculum from Mostyn, Milo and Orlando (Tables 5 and 6). This confirms that it has a high level of adult plant resistance which is additional to its hypersensitive overall resistance OMR 3 as the other OMR 3 cultivars Mostyn and Milo develop relatively high levels of mildew when inoculated with mildew from Mostyn, Milo and Orlando. Similar results were obtained also in Test 2, Rhiannon maintaining its high level of resistance (Tables 7 and 8).

Table 7. Percentage of Flag-1 leaf segments infected with mildew (Test 2) (means of two blocks, two boxes and three recorders)

Test cultivars		Inoculum source: Mostyn (OMR 3)	Milo (OMR 3)	Cabana (OMR 2)	Trafalgar (OMR 2)	Orlando (OMR 2)	Mean
Selma	(OMR 0)	8.9	0.0	29.2	47.5	25.0	22.12
Mostyn	(OMR 3)	4.7	24.6	4.1	1.2	13.6	9.62
Milo	(OMR 3)	8.3	15.3	0.3	0.0	15.8	7.96
Rhiannon	(OMR 3)	0.0	3.2	1.5	0.1	5.1	1.97
Cabana	(OMR 2)	8.0	22.4	39.4	45.4	10.4	25.13
Trafalgar	(OMR 2)	6.7	8.9	27.9	20.2	14.7	15.68
Orlando	(OMR 2)	11.0	21.8	20.7	6.9	9.8	14.03
Mean		6.80	13.75	17.58	17.33	13.48	13.79

Table 8. Mean percentage Flag-1 leaf segment area infected +1.0 (Test 2) (logit transformation)

Test cultivars		Inoculum source: Mostyn (OMR 3)	Milo (OMR 3)	Cabana (OMR 2)	Trafalgar (OMR 2)	Orlando (OMR 2)	Mean (LSD=±0.0787)
Selma	(OMR 0)	-1.2024	-2.2935	-0.4351	-0.0304	-0.6377	-0.9198
Mostyn	(OMR 3)	-1.6263	-0.5424	-1.6273	-2.0294	-0.9557	-1.3562
Milo	(OMR 3)	-1.2519	-0.8472	-2.2094	-2.2935	-0.8657	-1.4935
Rhiannon	(OMR 3)	-2.2976	-1.7804	-2.0276	-2.2683	-1.8181	-2.0384
Cabana	(OMR 2)	-1.2988	-0.7121	-0.2129	-0.0754	-1.0582	-0.6715
Trafalgar	(OMR 2)	-1.3418	-1.1907	-0.4581	-0.6882	-1.0331	-0.9424
Orlando	(OMR 2)	-1.0685	-0.6408	-0.7941	-1.2414	-1.0948	-0.9679
Mean (LSD=±0.0478)		-1.4410	-1.1439	-1.1092	-1.2324	-1.0662	-1.1985

LSD to compare inoculum source/test cultivar means = ±0.1760 (P = 0.05) and ±0.2955 (P = 0.001)

Mildew development on Milo compared with Mostyn is of special interest as the newer cultivar Milo in field trials has generally shown higher levels of adult plant resistance than its parent Mostyn. The prime objective of these experiments is to detect whether any adaptation has occurred to

such quantitatively expressed resistance. In Test 1 the inoculum from Milo attacked both Milo and Mostyn quite severely 40.0 versus 38.8 (Table 5), but the difference is not significant (Table 6).

In Test 2 (Table 7), when a higher leaf (Flag-1) of the test cultivar was used, Milo showed a significantly (P=0.001) lower level of infection of 15.3 compared with 24.6 on Mostyn when inoculated with inoculum from Milo, which is more in agreement with field observations. However, mildew from Mostyn attacked Milo more severely than Mostyn (Table 5) although the difference between 31.7 and 26.7 is not significant (Table 6), although in Test 2 the same comparison is significant at P = 0.001. The mildew from Orlando also produced significantly more infection on Milo than on Mostyn, the difference being significant in Test 1 but not in Test 2. There is no conclusive evidence of adaptation in Milo produced mildew to its own host, but the high level of infection on both Mostyn and Milo is a disturbing feature in Test 1, as also the higher infections on Milo than Mostyn from other inoculum sources.

Mildew from Cabana produced heavy infections on most test cultivars lacking OMR 3 resistance, and particularly on its own host giving 44.2 and 39.4 in Tests 1 and 2 respectively (Tables 5 and 7). Also as a test cultivar it was very susceptible to all isolates giving an overall mean of 52.25 and 25.13 (Tables 5 and 7), indicating a low level of resistance when corresponding virulence is present to its major resistance OMR 2.

Trafalgar, although with the same overall resistance (OMR 2), showed significantly lower mildew than Cabana whether inoculated with mildew produced on Trafalgar or Cabana.

The Orlando isolate was the least aggressive on its own host giving only 10.2 and 9.8% area infected (Tables 5 and 7). As a test cultivar it showed a low value of all isolates in Test 1, all of which had corresponding virulence to its specific overall resistance OMR 2. This is in contrast with the results from the isolate collected in the field in the previous season which showed high level of adaptation to its own host Orlando.

In general it appears this technique is working reasonably well, although further improvement in precision is desirable. Results from inoculum cultures which have been multiplied on their own hosts for several generations in isolation, as occurred in this season, probably do not reflect exactly the field situation. On the other hand, they may indicate what is likely to occur to the mildew population in the field and the possible durability of certain adult plant resistances. It is intended to continue these tests under field conditions in 1984 provided sufficient oat mildew infections occur.

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CROWN RUST OF OATS

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

Welsh Plant Breeding Station, Aberystwyth

Five samples of oat crown rust were received in 1983 from two locations in the south-west of England. Isolates of Puccinia coronata avenae cultured from the two spring oat cvs. Cabana and Trafalgar were virulent on the differential cvs. Appler, Bond, Ukraine and Saia. This virulence combination, which was also isolated from samples of the winter oat cvs Maris Quest and Bulwark, is identified on the international register as a race 275. The remaining isolate tested from cv. Peniarth differed from race 275 in being avirulent of the differential cv. Ukraine, but virulent on cv. Landhafer. This virulence combination was first detected in 1982.

VARIETY DIVERSIFICATION SCHEMES FOR WINTER WHEAT AND SPRING BARLEY, 1984

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 1984 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).

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VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST AND MILDEW IN WINTER WHEAT 1984

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 1B
Avalon
Bounty
Fenman
Longbow

DG 1C
Mission

DG 1E
Aquila
Flanders

DG 2B
Hustler
Maris Huntsman
Virtue

DG 3B
Norman

DG 4C
Armada

DG 6B
Brigand
Galahad

DG 6F
Hobbit
Moulin
Rapier

DG 7D
Stetson

DG 7G
Hammer

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.

Companion DGs

Chosen DG	DG 1B	DG 1C	DG 1E	DG 2B	DG 3B	DG 4C	DG 6B	DG 6F	DG 7D	DG 7G
DG 1B	m	+	+	m	m	+	m	m	+	+
DG 1C	+	m	+	+	+	m	+	m	+	+
DG 1E	+	+	m	+	+	+	+	m	+	+
DG 2B	m	+	+	ym	m	+	m	m	+	+
DG 3B	m	+	+	m	ym	+	m	m	+	+
DG 4C	+	m	+	+	+	ym	+	m	+	+
DG 6B	m	+	+	m	m	+	ym	ym	+	+
DG 6F	m	m	m	m	m	m	ym	ym	m	m
DG 7D	+	+	+	+	+	+	+	m	ym	y
DG 7G	+	+	+	+	+	+	+	m	y	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 1984

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.

DG 0
Golden Promise
Corgi

DG 1
Apex
Atem

DG 2
Carnival
Midas

DG 3
Cerise
Flare
Georgie
Golf
Koru
Kym
Sundance
Varunda

DG 4
Goldmarker
Goldspear

DG 5
Athos
Javelin
Patty
Piccolo

DG 6
Tasman
Triumph

DG 7
Delta

DG 8
Leith
Tweed

DG 9
Klaxon

DG 10
Egmont
Regent

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
DG 1	+	+	+	+	+	+	+	+	+	+
DG 2	+	m	+	m	+	+	+	+	+	+
DG 3	+	+	m	m	+	+	+	+	m	m
DG 4	+	m	m	m	+	+	+	+	m	+
DG 5	+	+	+	+	m	+	+	+	+	m
DG 6	+	+	+	+	+	m	+	+	m	+
DG 7	+	+	+	+	+	+	m	+	+	+
DG 8	+	+	+	+	+	+	+	m	+	+
DG 9	+	+	m	m	+	m	+	+	m	+
DG 10	+	+	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.