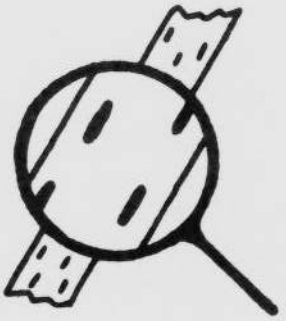
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1982 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

Chairman: Dr G D H Bell CBE FRS

Secretary: Dr R A Bayles, National Institute of Agricultural Botany,
Huntingdon Road, Cambridge, CB3 OLE
Tel: Cambridge (0223) 276381

1982 Annual Report

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MEMBERS OF THE UK CEREAL PATHOGEN VIRULENCE SURVEY COMMITTEE, 1982-83

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Dr R H Priestley	National Institute of Agricultural Botany, Cambridge
Mrs S E Slater	Plant Breeding Institute, Cambridge
Dr M S Wolfe	Plant Breeding Institute, Cambridge

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THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

The Survey, formerly the Physiologic Race Survey of Cereal Pathogens, commenced in 1967 following an unexpected epidemic of wheat yellow rust (*Puccinia striiformis*) which caused severe yield losses in the then recently introduced but 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 and measuring the effect of changes in cultivar on the pathogen population.

These objectives are supplemented by efforts to improve techniques, especially those for the detection of adult plant virulences, the recognition of durable resistance, the numerical analyses of results and detection of 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 and in Polythene tunnels in the following season.

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 to illustrate to students the principles of resistance in host-pathogen systems. 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 1982

Mildew of Wheat

Pathogenicity matching all the WMR groups present in commercial cultivars, and some combinations thereof, was found in samples collected in 1982. Mean pathogenicity varied according to the sampling method used and there were indications that certain WMV types were selected against in laboratory-maintained populations. Phenotypes insensitive to low doses of the SI chemical triadimenol were detected in large numbers.

Yellow Rust of Wheat

Virulence frequencies in samples received during 1982 were similar to those of 1981. There was no evidence in adult plant tests of virulence for previously resistant cultivars. WMR factors were identified for a number of recently introduced cultivars.

Brown Rust of Wheat

Virulence to the cultivar Sabre (WBR-7) was detected for the first time. Virulence to cultivars Virtue, Hustler, Rapier was not detected and these cultivars remain resistant. The susceptibility of cultivars Avalon and Bounty (WBR-9) was confirmed.

Mildew of Barley

No new or unusual pathogenicity genes or combinations were identified. The frequency of pathogenicity for BMR 6+Ab (cvs. Triumph, Tasman) continued to increase, but remained at low levels on non-corresponding hosts. Insensitivity to triazole fungicides continued to increase in England and the association of this character with pathogenicity for BMR 3 (cv. Midas, Carnival) was confirmed.

Yellow Rust of Barley

Virulence for Astrix (BYR 1) remained at 100% and virulence for Bigo (BYR 2)

increased to 96%. It was confirmed that cultivars Triumph, Tasman and Carnival possess resistance effective at the seedling stage but not at the adult plant stage.

Brown Rust of Barley

The previously occurring virulence pattern, octal 673, was again common, but a new one, octal 653, was detected for the first time on cv. Triumph and was virulent on both Triumph and Carnival.

Rhynchosporium of Barley

The range of known races (UK 1-5) was detected and a new virulence combination, designated Race UK 6 (BRV 3 + 4) was identified. Three isolates of UK6 also have high levels of infection on cv. Hoppel as well as Igri and Athene. Under field conditions, isolates possessing BRV 4 (Igri virulence), failed to cause significant infection on adult plants of cv. Igri. Cvs Tipper and Gerbel appear to carry BRR-2, overcome by the common races UK-2 and UK-5.

Net Blotch of Barley

Virulence to winter cultivars was common in seedling tests but this does not correspond with reported field resistance. Virulence to important sources of resistance for breeders occurred at low frequencies.

Mildew of Oats

In addition to the commonly occurring OMV 1 + 2 (race 3) and OMV 1 + 2 + 3 (race 5), four samples had virulence to the resistance derived from Avena barbata (OMR 4). These four isolates possessed the virulence combination OMV 1 + 2 + 3 + 4, making them capable of attacking all the seedling resistance factors at present available in commercial oat cultivars and breeding lines.

Crown Rust of Oats

The only race identified was similar to race 372, but avirulent on Ukraine. This is agriculturally unimportant at present.

MILDEW OF WHEAT

Fiona G.A. Bennett and Thea van Kints

Plant Breeding Institute, Cambridge

A low number of conventional leaf samples was received. Increased use of the wind impaction spore trap (WIST) provided more samples than in previous years. The mean pathogenicity averaged over the previous three years obtained from analysis of the two types of sample was compared. Values obtained from WIST samples were usually slightly higher than those from leaf samples. This was most marked for WMV 4 and it was concluded that WMV 4 was at a selective disadvantage on non-matching hosts.

Direct assessment of pathogenicity using the WIST indicated great variability between regions. Overall mean pathogenicity obtained by this method was of the same order as by the two previous methods except that WMV 7, WMV 5+8+?, WMV 2+4+6 and WMV 2+6+7 pathogenicities were considerably higher, suggesting that genotypes carrying these characters do not compete well in laboratory-maintained isolates. This finding was confirmed in direct and indirect tests of corresponding populations in East Anglia.

The influence of triadimenol seed treatment of selective hosts on mean pathogenicity in WIST samples was tested. Whereas WMV 2+6 pathogenicity was generally higher in fungicide insensitive isolates, WMV 4, WMV 5+8+? and WMV2+4+6 were dramatically reduced in insensitive isolates. The implication of this finding for cultivar diversification and mixing schemes was discussed.

Direct tests for fungicide insensitivity using the WIST showed that East Anglian populations had, on average, a higher proportion of phenotypes insensitive to 0.025 g a.i. triadimenol kg^{-1} seed than elsewhere. Indirect tests of the same populations showed that a greater range and proportion of insensitivity was present in populations after the main field application of related SI chemicals. In contrast, only the proportions of phenotypes insensitive to lower concentrations of the chemical were increased by increasing the selective dose.

Comparison of WIST samples from untreated and triadimenol treated seedlings demonstrated that insensitive isolates were less competitive than sensitive ones in the absence of the selective agent.

INTRODUCTION

The severe winter weather delayed the start of the epidemic in 1982. ADAS Disease Intelligence Reports showed that mildew caused concern only in the Eastern Region, remaining confined to lower leaves elsewhere. These factors probably account for the much reduced number of conventional leaf samples received in 1982, the lowest since 1975. However, more samples were collected using the wind impaction spore trap (WIST; CPVS 1980, p 4, 43), especially in the Eastern Region.

Since there were only six wheat mildew resistance (WMR) groups represented in commercially grown cultivars in 1982, namely WMR 0, 2, 4, 7, 8 and 2+6, the same differential cultivars were used as previously (Table 1).

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
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[1], Maris Huntsman[2]
5+8+?		Sicco
2+4+6		Timmo
2+6+7		CWW1645/5
2+6+8		Crossbow
?		Stetson

$^{\phi}$ Not included in tests for this report: not relevant to commercial cultivars
$\dagger$ Not tested by present authors
* Temporary symbols
[1,2] Superscripts denote differential cultivars for same WMR group

Stetson was also included since it was thought to possess a novel combination of resistance genes.

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 2. Details of conventional leaf samples received in 1982

WMR Group	Source cultivar	Received	Fungicide treated	Failed to establish	Died in culture
0	Abele	1	0	1	0
	Hobbit	3	1	1	0
	Rapier	6	0	3	1
2	Avalon	5	0	2	1
	Avocet	1	0	1	0
	Bounty	1	0	1	0
	Fenman	1	0	1	0
	Galahad	1	0	1	0
	Longbow	1	0	1	0
	Norman	3	0	1	2
4	Armada	7	1	4	0
6	Triticum timopheevi	1	0	0	0
7	Stuart	2	0	2	0
8	Aquila	3	0	1	1
2+6	Brigand	6	1	4	0
	Hustler	4	0	2	0
	Virtue	7	0	2	1
5+8+?	Sicco	1	0	0	1
2+4+6	Timmo	2	0	1	1
(Sona 227)	Highbury	1	0	1	0
?	Musket	1	0	0	0
	Total	58	3	30	8

* Only ergosterol-biosynthesis inhibiting chemicals included, i.e. Bayleton, Tilt.

METHODS

Sampling

Details of conventional leaf samples received (Table 2) and WIST samples collected are given in Tables 2 and 3 respectively.

The majority of WIST samples came from the Eastern Region where the disease caused most concern. In addition to occasional journeys into Norfolk and other parts of the country, two standard circuits were travelled at regular intervals. One, the Cambridge run, circled Cambridge in a 80 km transect. The other, the Essex run, was a 190 km transect to the south-east of Cambridge.

Table 3. Details of WIST samples collected in 1982

Trap cultivar or group of cultivars	WMR	Seed treatment (triadimenol)	No.	Failed to establish	Died in culture
Cerco	0	Untreated	62	1	13
		*† 0.025	51	1	9
		† 0.04	11	0	2
		† 0.125	9	0	0
Hobbit	0	Untreated	4	0	0
		† 0.04	2	0	1
		† 0.08	2	0	1
		† 0.125	1	0	0
		† 0.25	1	0	0
		0.375	2	0	1
Armada	4	Untreated	16	0	2
Spring lines	Various	Untreated	10	0	1
Winter lines & cultivars	Various	Untreated	78	1	13
Total			249	3	43

* All concentrations given in g a.i. triadimenol per kg seed
† Treated by Bayer UK Ltd.

The lower establishment failure rate amongst WIST samples (Table 3) compared with leaf samples (Table 2) was an obvious advantage of this sampling method. The failure to establish isolates from any of the three leaf samples taken from fungicide treated crops may not be coincidence. This effect was not apparent in WIST samples collected on seedlings grown from treated seed.

All samples from untreated host material were maintained on the susceptible cultivar Cerco. WIST samples collected on seedlings grown from triadimenol treated seed were all maintained on Cerco treated at the rate of 0.025 g a.i. kg^{-1}seed.

Testing

Differential tests were carried out as described previously (CPVS 1981, p 5), colony numbers being counted automatically and mean pathogenicity values subsequently calculated.

Isolates from the mixture trial (Table 2) were also tested on a restricted range of cultivars corresponding to those represented in the trial. WIST isolates collected on treated host material were subsequently tested on Hobbit seedling leaves grown from untreated seed and seed treated with 0.04, 0.08, 0.125, 0.25, 0.375 and 0.625 g a.i. triadimenol kg^{-1} (all obtained through J.T. Fletcher, ADAS from Bayer UK Ltd.). Four leaf segments at each concentration were separated in pairs from all others by placing them in small, polystyrene boxes. Thus for each isolate, 14 small boxes containing the test leaves were placed together in a settling tower for inoculation. Colony numbers were later counted visually. Certain WIST isolates collected on untreated host material were also tested in this way.

RESULTS AND DISCUSSION

Differential tests

1. Conventional leaf samples

Table 4 shows the results obtained by testing samples on detached leaf segments of differential cultivars. As in previous years, isolates generally showed the highest pathogenicity on differentials matching the host cultivar from which they were derived.

Stetson was resistant to all isolates except one from Brigand. Although the suggestion has been made (N.H. Chamberlain, pers. comm.) that Stetson belongs to WMR 2+6+7, Table 4 shows that the differential for this group is more frequently susceptible than Stetson.

2. WIST samples

Bulk isolates made from samples collected from untreated Cerco seedlings exposed on WIST journeys gave similar results to the previous two years (lower half, Table 5). Thus pathogenicity matching all the WMR groups for which differentials were included could be found in the air spora.

Table 4. Mean pathogenicity of 19 bulk isolates received in 1982

WMR group	Source Cultivar	Wheat mildew virulence (WMV) group as represented by differential cultivars* 2	4	5	6	7	8	2+6[1]	2+6[2]	5+8+?	2+4+6	2+6+7	2+6+8	Stetson	Number of isolates
0	Hobbit	97	4	90	74	0	87	100	113	3	0	0	85	0	2
	Rapier	95	1	54	64	0	43	85	70	48	0	0	58	0	2
2	Avalon	84	52	57	73	0	60	71	95	0	0	1	47	0	2
4	Armada	77	83	65	44	0	67	59	69	1	0	1	49	0	3
6	T. timopheevi	62	0	66	21	0	64	7	3	50	3	0	15	0	1
8	Aquila	97	0	83	90	0	112	89	99	0	0	0	76	0	1
2+6	Brigand	109	1	91	75	0	88	99	108	1	0	1	75	2	1
	Hustler	96	10	30	65	0	47	57	83	5	4	3	19	0	2
	Virtue	86	23	59	88	0	64	78	111	15	8	<1	75	0	4
?	Musket	104	103	82	24	0	106	7	3	67	34	0	4	0	1

* Differential cultivars given in Table 1.

Table 5. Comparison of mean pathogenicity of conventional leaf samples, 1979-1982 (excluding values for samples from cultivars with matching resistance), with WIST samples from untreated Cerco seedlings 1980-1982

Type of Sample	Year	WMV group as represented by differential cultivars* 2	4	5	6	7	8	2+6[1]	2+6[2]	5+8+?	2+4+6	2+6+7	2+6+8	Stetson	Number of Samples
CPVS -leaf samples	1979	47	4	42	28	0	39	-	30	18	2	-	-	-	59
	1980	72	22	54	35	4	56	48	35	31	7	-	25	-	114
	1981	77	37	65	64	1	58	82	60	29	22	4	39	-	32
	1982	86	15	63	59	0	64	71	79	13	2	1	57	0	18
mean	80-82	75	24	57	43	3	57	57	45	29	9	3	46	0	(165)
WIST -trap samples	1980	73	45	68	30	6	68	57	43	29	12	-	20	-	38
	1981	85	53	89	68	2	75	57	50	37	13	2	45	-	28
	1982	96	35	68	73	2	80	96	78	16	17	1	78	2	17
mean	80-82	82	46	75	52	4	77	65	53	29	13	2	57	2	(83)

* differential cultivars given in Table 1.

When these results are compared with those obtained from analysis of conventional leaf samples on non-matching hosts (upper half, Table 5), pathogenicity values of the same order are obtained for all WMR groups, despite the small number of samples involved. However, as in previous years, results for the WIST samples are all slightly higher than those for the leaf samples, suggesting that selection against non-matching pathogenicity types occurs on hosts in all WMR groups. This effect is particularly noticeable for WMV 4 and occurs consistently over years. Indeed, when results for the three years 1980-1982 are averaged, it can be seen that whilst WMV 4 was quite rare in isolates collected from non-matching hosts, it was relatively common in the air spora. This supports the previous conclusion (CPVS 1981, p 11) that WMR 4 cultivars would be particularly useful in diversification and mixing schemes.

A further increase in WMV 2, WMV 6 and WMV 2+6 pathogenicity occurred in 1982 in line with the increasing proportion of recommended cultivars in matching WMR groups (NIAB Farmers Leaflets No. 8). There was also a large increase in WMV 2+6+8 pathogenicity, which was to be expected as the component pathogenicity types were all frequent in the samples analysed.

In order to investigate further the behaviour of WMV 4 pathogenicity in populations, both leaf and WIST samples obtained from and maintained on cv. Armada (WMR 4), were compared by inoculation on to the standard set of differentials. A priori WMV 4 pathogenicity was expected to be similar in the two sample types. However, there were inconsistencies in the data which cannot readily be explained and may have been due to the relatively small number of samples involved. Further similar work is required before any conclusions can be drawn.

3. Direct and indirect differential tests

Selection amongst genotypes is known to occur in bulk isolates maintained for a long period of time. This problem affects all laboratory-maintained isolates, whatever their origin, and can only be partially avoided by maintaining isolates on their source cultivars, a method impractically labour-intensive for large numbers of isolates. Some indication of which WMV types may or may not be at a selective advantage or disadvantage in maintained isolates was sought by exposing differential cultivars in the WIST in a direct differential test (Table 6). Populations varied considerably from place to place, only WMV 2 and 5+8+? being common everywhere. When the mean of these results is compared with the 1982 WIST

Table 6. Mean pathogenicity of mildew populations sampled directly by exposing differential cultivars in the WIST on approx. 80 km transects of journeys to various NIAB trial sites on different dates.

Date of Sampling	Region	WMV group as represented by differential cultivars*											
		2	4	5	6	7	8	2+6 [1]	2+6 [2]	5+8+?	2+4+6	2+6+7	2+6+8
28/4	Norfolk (Morley)	310	36	176	66	0	62	228	200	12	0	42	86
11/5	Norfolk (Terrington)	172	50	103	0	0	55	0	0	183	0	0	61
12/5	Yorkshire (Headley Hall)	80	0	0	0	0	0	125	114	50	0	25	0
26/5	Kent (Wye)	110	61	46	92	37	17	105	52	92	0	26	18
17/6	Norfolk (Morley)	198	89	161	46	15	99	190	147	80	0	31	103
Mean		174	47	97	41	10	47	130	103	83	0	25	54
WIST 1982 mean (from Table 5)		96	35	68	73	2	80	96	78	16	17	1	78

* Differential cultivars given in Table 1

Table 7. Comparisons of mean pathogenicity results obtained directly by exposing differential cultivars in the WIST or by indirect analysis of samples collected on untreated Cerco seedlings exposed in the WIST on the same Cambridge or Essex circuit at similar dates

Method of Sampling	Date of Sampling	WMV group as represented by differential cultivars* 2	4	5	6	7	8	2+6 [1]	2+6 [2]	5+8+?	2+4+6	2+6+7	2+6+8	Circuit
Direct	28/5	129	80	119	64	32	74	125	96	43	12	25	46	Essex
Indirect	13/5	105	29	8	47	0	88	83	82	0	10	0	57	
Direct	25/5	282	77	128	51	11	91	179	170	29	19	41	120	Cambridge
Direct	8/6	63	28	0	28	19	86	45	-	25	12	-	25	
Indirect	1/6	76	108	66	55	0	93	104	96	0	10	0	69	
Direct	26/6	175	19	146	58	31	111	189	187	19	26	0	29	Cambridge
Indirect	18/6	49	37	43	75	1	64	47	70	0	0	2	42	
Direct	2/7	229	53	177	64	7	62	150	169	64	27	25	73	Cambridge
Direct	9/7	271	62	96	47	50	104	171	167	25	13	21	83	
Indirect	9/7	117	8	134	65	0	103	107	70	4	0	0	68	
Direct	23/7	172	29	77	0	14	29	136	67	9	12	14	54	Cambridge
Indirect	1/9	109	0	85	113	1	117	105	112	0	0	0	103	

* Differential cultivars given in Table 1.

sample results in Table 5 (lower half), the most obvious differences occur in relation to WMV 7, 5+8+?, 2+4+6 and 2+6+7.

Confirmation of these results is given in Table 7 where results obtained by direct exposure of differential cultivars are compared with results from indirect tests of WIST samples collected on the same circuits at similar times. The competitive disadvantage of WMV 7, 5+8+? and 2+6+7 in maintained isolates is obvious. The same appears to be true for WMV 2+4+6 in samples collected later in the season. Thus conclusions drawn from indirect tests (Tables 4 & 5) that these pathogenicity characters are generally rare in populations could be misleading. This finding may account for the unexpected susceptibility of any WMR 7 cultivar when grown even in small plots and for the unheralded breakdown of the WMR 2+4+6 combination of resistance in cv. Timmo. Direct assessment of the pathogenicity spectrum of mildew populations should therefore be considered an important additional survey tool.

4. The effect of host seed treatment on pathogenicity

Following the observation in 1981 that mean pathogenicity of WIST samples collected on triadimenol treated and untreated Cerco seedlings (classified as insensitive and sensitive isolates respectively) differed (CPVS 1981, p 9), similar comparisons were made for 1982 samples. Comparable samples from the two regular circuits (Table 8), from different trap cultivars and from different times of the season (Table 9) were tested on the differential test cultivars. Although the previousfinding that isolates from treated seedlings generally showed lower pathogenicity than those from untreated seeedlings was not repeated, WMV 2+6 pathogenicity again appeared to be increased in isolates from treated seedlings. Thus there seems to be a positive association between fungicide insensitivity and WMV 2+6 pathogenicity. However, a negative association is apparent for WMV 4, 5+8+? and 2+4+6, the pathogenicity of which is uniformly and dramatically reduced in insensitive isolates. Therefore in cultivar diversification or mixing schemes which might incorporate fungicide treatment as a component, more value would be derived for example, from treating WMR 4 cultivars than WMR 2+6 cultivars.

Fungicide insensitivity tests

1. Direct tests with the WIST

By travelling over the same Cambridge and Essex circuits at regular intervals throughout the season, exposing seedlings grown from seed treated at different concentrations with the sterol inhibiting (SI) fungicide,

Table 8. Comparison of mean pathogenicity of WIST samples trapped on cv. Cerco seedlings grown from untreated and treated seed

Source of Samples	Treatment†	WMV group as represented by differential cultivars*													Number of Samples
		2	4	5	6	7	8	2+6 [1]	2+6 [2]	5+8+?	2+4+6	2+6+7	2+6+8	Stetson	
All samples collected in 1982	-	96	35	68	73	2	80	96	78	16	17	1	78	2	17
	+	97	17	61	78	0	69	92	90	1	6	0	72	0	30
Samples from corresponding circuits only	-	93	41	68	68	1	74	85	72	22	26	1	70	0	13
	+	99	20	68	73	0	69	89	84	2	8	0	69	0	22
Samples from Cambridge circuit	-	88	38	82	77	1	94	91	87	1	3	1	70	0	4
	+	89	10	62	78	0	71	93	95	0	2	0	77	0	11
Samples from Essex circuit	-	108	42	63	84	3	95	97	84	22	22	3	91	0	6
	+	101	11	64	74	0	67	80	74	0	0	1	56	0	8

* Differential cultivars given in Table 1
† -= untreated; += seed treated with triadimenol

Table 9. Comparison of mean pathogenicity of WIST samples trapped on different host cultivars, grown from untreated and treated seed, at different times during the season

Cultivar used to trap samples	Time	Treatment†	WMV group as represented by differential cultivars*													Number of Samples
			2	4	5	6	7	8	2+6 [1]	2+6 [2]	5+8+?	2+4+6	2+6+7	2+6+8	Stetson	
Hobbit	Through-out season	-	94	61	79	56	1	71	57	65	47	50	0	73	0	3
		+	101	22	103	80	<1	85	94	84	8	<1	1	80	1	5
Cerco	Through-out season	-	96	35	68	73	2	80	96	78	16	17	1	78	2	17
		+	97	17	61	78	0	69	92	90	1	6	0	72	0	30
Cerco	Before and during flowering	-	72	70	60	75	0	85	72	77	22	36	1	54	0	4
		+	93	14	45	71	0	55	80	69	0	0	0	55	0	9
Cerco	After flower-ing	-	104	24	70	72	2	79	103	78	14	11	1	86	2	13
		+	98	18	68	82	0	75	98	99	1	9	0	79	0	21

* Differential cultivars given in Table 1.
† -= untreated; += seed treated with triadimenol

triadimenol, direct assessments of changes in fungicide insensitivity of mildew populations could be made. The results of such exposures are shown in Figures 1a & 1b. There was considerable variation in percentage insensitivity assessed in this way but the figures show that insensitive phenotypes were being generated in large numbers throughout the season. As expected higher concentrations of the chemical on trap seedlings selected a smaller number of insensitive phenotypes.

Using this method of assessment of fungicide insensitivity elsewhere in the UK showed again that there was considerable variation in the proportion of populations insensitive to 0.025 g a.i. kg^{-1} of the fungicide (normal field rate 0.375 g a.i. kg^{-1}) but that this proportion was closely associated with the intensity of wheat growing (and therefore use of related SI chemicals) in particular areas. The highest values were obtained in East Anglia (Essex mean, 58%; Cambridge mean, 48%; Norfolk circuit on 8/7, 39%) and the north-east (42%). Lincolnshire and the Midlands were intermediate (21% & 24% respectively) whilst further north levels dwindled to 13% in south-east Scotland and 0% in Aberdeenshire. It should be noted that in total very few spores were caught north of Dunbar. In Kent, early in the season, 5% insensitivity was recorded.

2. Indirect tests of isolates collected in the WIST

Further information about the distribution of insensitive phenotypes in populations can be obtained by controlled laboratory testing of isolates collected in the WIST on a range of concentrations of triadimenol. When the percentage of isolates selected on 0.025 g a.i. kg^{-1} and insensitive to 0.04 g a.i. kg^{-1} in indirect tests was compared with the percentage of populations insensitive in direct tests to 0.025 g a.i. kg^{-1} on the same journeys, there was a significant but not high positive correlation ($r=0.67$, $P<0.1$). This indicates that considerable environmental variation must be attached to the direct results obtained with the WIST.

In Table 10 the percentage of insensitivity in populations selected on increasing concentrations of the chemical was compared. Higher selective concentrations appeared to increase the percentage of phenotypes insensitive at the three lower concentrations of the chemical rather than to increase the range of insensitivity. Therefore a shift in the population distribution does not appear to have taken place at higher dose rates, merely an increase in the proportion of moderately insensitive phenotypes.

Figure 1. Mean colony number per seedling on cv. Cerco seedlings grown from seed treated with 0.025 g a.i. (□), 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) the 80 km Cambridge circuit and b) the 190 km Essex circuit on dates between 24 May and 3 August 1982

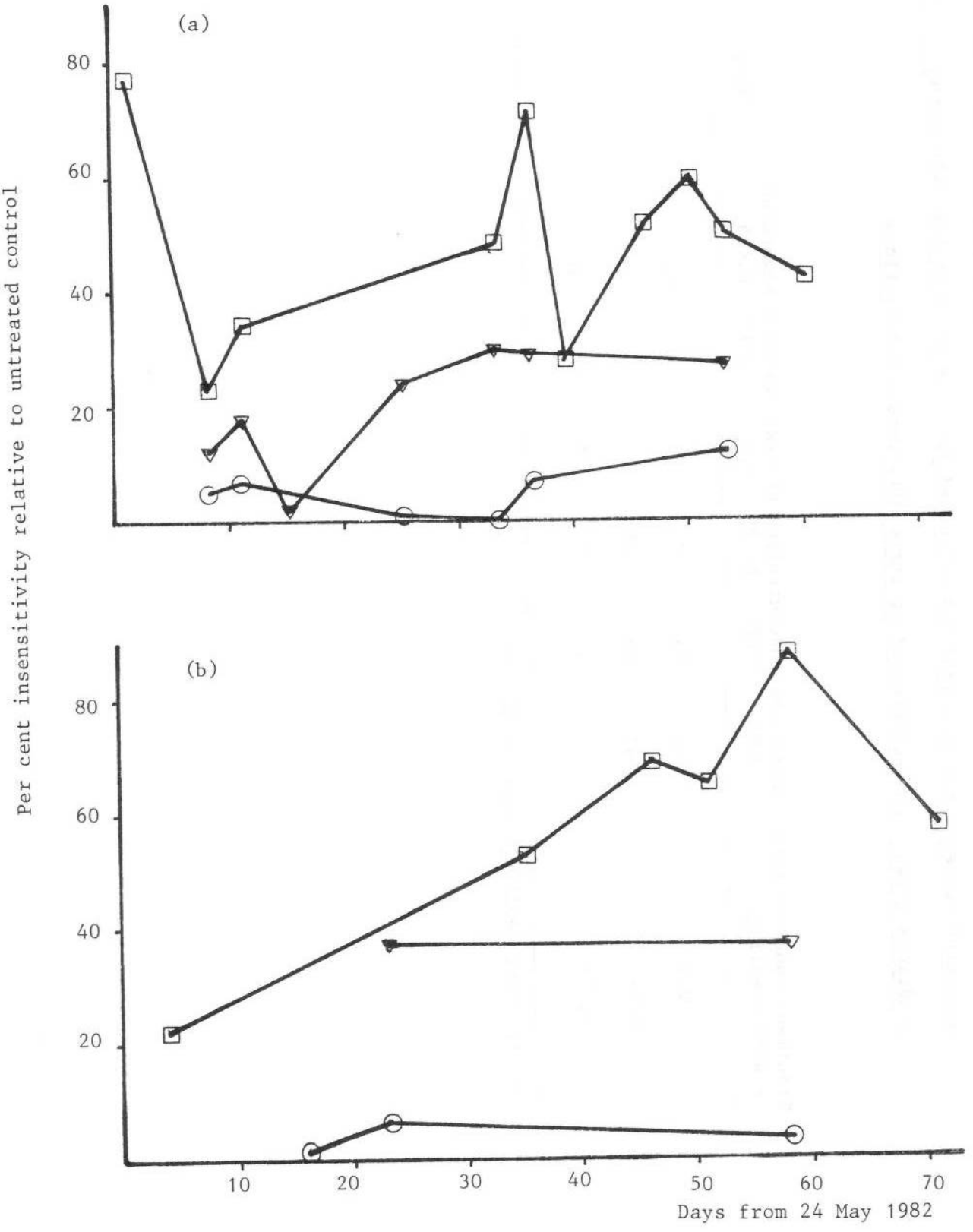

Table 10. Colony numbers on leaf segments grown from triadimenol-treated seed as a percentage of those on untreated segments for bulk isolates collected in the WIST throughout the season on cv. Cerco seedlings grown from seed treated at three different concentrations

Treatment concentration of WIST seedlings	Treatment concentration of test seedling segments*						Number of isolates
	0.04	0.08	0.125	0.25	0.375	0.625	
0.025	61	33	20	3	1	<1	32
0.04	62	30	15	4	1	0	9
0.125	80	50	24	2	0	0	6

* All test seedlings were cv. Hobbit

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 seedlings grown from triadimenol-treated seed before and after 18th June 1983 in East Anglia

Period of Sampling	Treatment concentration of test seedling segments*						Number of isolates
	0.04	0.08	0.125	0.25	0.375	0.625	
Pre-flowering	62	21	5	<1	<1	0	17
Post-flowering	70	48	33	5	2	<1	22

* 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 in East Anglia on cv. Cerco seedlings grown from seed treated at three different concentrations before and after 18th June 1983

Treatment concentration of WIST seedlings	Period of Sampling	Treatment concentration of test seedling segments* 0.04	0.08	0.125	0.25	0.375	0.625	Number of isolates
0.025	Pre-flowering	55	11	1	0	<1	0	9
	Post-flowering	68	45	33	5	2	<1	17
0.04	Pre-flowering	71	27	13	0	0	0	5
	Post-flowering	54	53	27	16	3	0	2
0.125	Pre-flowering	69	40	8	2	0	0	3
	Post-flowering	90	60	40	2	0	0	3

* All test seedlings 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 treated and untreated seedlings of cv. Cerco on corresponding circuits

Seed Treatment of WIST seedlings	Treatment concentration of test seedling segments*						Number of isolates
	0.04	0.08	0.125	0.25	0.375	0.625	
-	13	2	< 1	0	0	0	16
+	62	41	26	5	1	0	24

* All test seedlings were cv. Hobbit

A similar inference does not apply when the results for insensitive isolates are divided according to the time of collection (Table 11). In 1982 the major application of SI fungicides to wheat occurred between ear emergence and flowering (mid-June), after which spraying was not recommended. Those collected after this time showed a considerably increased proportion and range of insensitivity indicating a genuine shift in the population distribution and an increase in the population mean for insensitivity. In other words it appears that, as a result of SI chemical application, a greater number of phenotypes insensitive to higher fungicide concentrations survive in the population. It remains to be seen whether this change is maintained or whether removal of the selection pressure will result in a reversion to the former situation.

In order to elucidate these population changes still further, results for East Anglian isolates were broken down according to selective concentration and time of collection (Table 12). The most obvious increases in percentage insensitivity in samples collected after SI chemical application occur at the test concentration of 0.125 g a.i. kg^{-1} seed, and those samples selected on the lowest fungicide concentration display the largest change. If these population shifts are maintained, it might be expected that phenotypes selected on higher concentrations of the fungicide will be more affected in future years.

A final important comparison to be made is that between corresponding isolates collected on untreated and on treated host material (Table 13). Results for these two sets of isolates are not correlated. Thus it appears that in the absence of the selective agent, triadimenol, insensitive phenotypes are much less competitive than sensitive ones and will therefore not generally be expected to survive well on untreated crops. Nevertheless, the direct WIST observations show that insensitive phenotypes are being generated in large numbers and with continuing selection pressure, a reduction in effectiveness of the chemical might be expected.

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YELLOW RUST OF WHEAT

Rosemary A Bayles and R H Priestley

National Institute of Agricultural Botany, Cambridge

53 samples were received during 1982, which is about half the number in 1981. Seedling tests revealed virulence frequencies similar to 1981.

In adult plant tests with 1981 isolates, a large number of cultivars showed good resistance to all isolates. Results confirmed that Guardian and Pageant resembled WYR 13 cultivars. Isolates virulent on Hobbit (WYR 14) also showed increased virulence for Brigand. Comparison of the interactions of Maris Freeman, Maris Ranger and Kinsman (WYR 6) with two isolates confirmed the view that Maris Freeman and Maris Ranger possess an additional resistance not present in Kinsman. Abele and Baron, which resembled Clement (WYR 9) at the seedling stage, possessed adult plant resistance for which no corresponding virulence was detected. Galahad interacted with an isolate virulent on Maris Templar (WYR 1) and Hobbit (WYR 14) indicating that it possesses WYR 1,14.

Of eight 1981 isolates, two resembled WYV 13 control isolates, two resembled WYV 14 isolates, one possessed virulence for Clement and Stuart (WYR 9) and three possessed virulence for the overall resistances WYR 1,2,3, with no additional virulence for adult plant resistance. There was no evidence of virulence for previously resistant cultivars.

INTRODUCTION

The principal aim of the wheat yellow rust survey is the early detection of increased virulence in Puccinia striiformis compatible with resistances being exploited in commercial cultivars and breeding lines. Methods of detecting increased virulence and the current UK detection system have been described by Priestley (1978).

Specific resistances (WYR factors) identified in wheat cultivars to date, the resistance genes where known, a test cultivar possessing each resistance and the year of first detection of virulence (WYV) in the UK population of P. striiformis are given in Table 1. If increased virulence is not found after a few years in a variety which is widely grown, it is an indication that the resistance may be of a durable nature.

VIRULENCE TEST METHODS

Seedling tests with 1982 isolates

A total of 53 samples was received during 1982. This is about half the number

received in 1981 and reflects the relatively low incidence of P. striiformis in the field in 1982. The samples had been collected in a non-random way from Hustler (7 samples), Brigand (6), Guardian (6), Virtue (6), Vuka (5) and 20 other cultivars.

Isolates were made successfully from 41 samples. The remaining 12 failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Sappo.

Seedling tests were carried out on each isolate to determine the presence of virulence factors compatible with specific resistances WYR 1-10 (Table 1).

Table 1 Resistance factors to P. 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	-	Overall	Riebesel 47/51	1974
WYR 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 (1961); overall resistances are effective at all growth stages, adult plant resistances are ineffective at seedling growth stages.

. = virulence not yet detected

Adult plant tests with 1981 and control isolates

Seventeen isolates and an isolate mixture were tested for virulence compatible with both overall and adult plant resistance using the Polythene tunnel technique described by Priestley and Byford (1978) and seedling tests in controlled environment chambers (18°C/11°C, 16 hour light period). The isolates comprised seven controls of known virulence, eight collected in 1981, two from inoculated plots and a mixture of the remaining 1981 isolates. (Table 2)

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

Code	Cultivar	Region*	Site	WYV factors
Control Isolates				
71/493	Capta	S	Duns	WYV 1,2,3,7
72/852	Maris Ranger	EM	Market Harborough	WYV 2,3,4,6,12
75/109	Kinsman	WM	Harper Adams	WYV 2,3,4,6,
76/15	Clement	EM	Boston	WYV 2,3,4,8,9,
76/71	Grenade	S	Mains of Ravensby	WYV 1,2,3,13
77/26	Hobbit	EM	Tydd St Mary	WYV 1,2,3,14
80/32	Bounty	EM	Grainthorpe	WYV, 1,2,3,
1981 Isolates				
81/2	Bounty	E	Morley	WYV 1,2,3,(6)
81/4	Vuka	SW	Cirencester	WYV 1,2,3,(6),(7)
81/11	Bounty	WM	Netherton	WYV 1,2,3
81/14	Bounty	E	Terrington	WYV 1,2,3
81/34	Vuka	S	Sparsholt	WYV 2,3,4,9
81/37	Pageant	WM	Drayton EHF	WYV 1,2,3
81/57	Longbow	N	Shoreswood Cockle Pk	WYV 1,2,3
81/60	Guardian	E	Terrington	WYV 1,2,3
Other Isolates				
81/A1	Clement inoculated with YRW 80/A4			WYV 2,3,4,8,(9)
P75/27	Hobbit inoculated with YRW 73/23			WYV 2,3,4,14
82 mix	Mixture of 1981 isolates			

( ) partially virulent on corresponding resistance

* S, Scotland; EM, East Midlands; WM, West Midlands; SW, South Western; E, East; N, Northern.

In adult plant Polythene tunnel tests, two replicate tussocks of 36 cultivars were sown on 25-26 November, inoculated on 30 March and 15 April, and assessed for percentage leaf area infection on 7 May (GS 37), 21 May (GS 50), 4 June (GS 64) and 18 June (GS 75).

VIRULENCE TEST RESULTS

Sampling was not carried out on a random basis and virulence frequencies shown for 1976-1982 (Table 3) should therefore be interpreted with caution. The frequencies of individual virulence factors were broadly similar to previous years, although there is some evidence of a decline in the frequency of WYV 1 and an increase in the frequency of WYV 4. The inverse relationship between the frequencies of WYV 1 and WYV 4 has been maintained during recent years. The possibility that the genes concerned may be allelic or linked in repulsion has been discussed by Priestley and Byford (1979). Detailed data on virulence frequencies reveals that, in 1980, 2 isolates possessed the combined virulences WYV 1 + WYV 4, from which it may be concluded that the genes concerned are not allelic. WYV 8 was detected for the first time since 1977 and WYV 7 and WYV 9 were again detected after their re-appearance in 1981.

Seedling tests with 1982 isolates

Table 3 Virulence factor frequency (%)

WYV factor	Common Name	1976	1977	1978	1979	1980	1981	198
WYV 1	Chinese 166 virulence	92	73	73	83	95	71	63
WYV 2	Heine VII virulence	100	100	97	100	100	100	100
WYV 3	Vilmorin 23 virulence	100	100	100	100	85	95	100
WYV 4	Hybrid 46 virulence	12	24	27	17	15	29	37
WYV 5	T. Spelta album virulence	0	0	0	0	0	0	0
WYV 6	Heine Kolben virulence	4	16	26	17	25	31	29
WYV 7	Lee virulence	0	8	0	0	0	5	5
WYV 8	Compair virulence	2	4	0	0	0	0	2
WYV 9	Riebesel 47/51 virulence	6	0	0	0	0	5	2
WYV 10	Moro virulence	0	0	0	0	0	0	0
	number of isolates tested	52	26	26	30	20	42	41

Adult plant tests with 1981 and control isolates

Average infection levels (mean of four assessments) and seedling reactions are given in Table 4. A multivarate analysis of the data was carried out (as described by Priestley and Byford, 1979). Table 5 gives 2-factor residuals and the corresponding cultivar and isolate dendrograms derived by average linkage cluster analysis (Sneath and Sokal, 1973). The main use of the dendrograms here is to assist in identifying pairs or groups of varieties or isolates which are closely linked (% similarity values approximately 90% or greater) and are therefore judged to be similar.

One of the main features of the results was the large number of cultivars showing good resistance to all isolates, which is reflected in the dendrogram by a large group of highly similar cultivars. Of these, seven cultivars (Aquila, Fenman, Stetson, Abele, Baron, Avocet and Longbow) were resistant to all isolates and were consequently very closely linked on the cultivar dendrogram. A second, highly similar group of cultivars (Flanders, Galahad, Rapier, Avalon, Bounty and Armada), were resistant to most isolates and gave only very low infection levels with certain isolates.

Three cultivars (Avocet, Galahad and Stetson), were included in Polythene tunnel tests for the first time in 1982. Avocet was resistant to all isolates. Evidence from routine NIAB seedling tests indicates that both Avocet and Longbow possess the overall resistance factors WYR 1,2,6. The corresponding virulence combination, WYV 1,2,6, was absent from all isolates used in 1982. Stetson was resistant to all isolates and has also been so in routine NIAB seedling tests, indicating that it possesses resistance for which there is currently no corresponding virulence. Galahad interacted with isolate 77/26 but not isolate 75/27, suggesting that it possesses the WYR 14 adult plant resistance, in combination with the overall resistance WYR 1.

Guardian was highly susceptible to certain isolates, interacting particularly with isolates 80/32, 76/71 (as previously reported (Priestley, Bayles & Crofts, 1982)) and 81/11. These isolates tended to interact positively with WYR 13 cultivars (Box A), confirming that Guardian may also possess this specific resistance, but with less background resistance than the other cultivars.

Pageant interacted with isolates in a manner similar to Hustler (WYR 13) and probably therefore possesses WYR 13. There were some indications from 1981 dendrograms that Pageant resembled WYR 13 cultivars (Priestley, Bayles and Crofts, 1981), despite an anomalous high residual with isolate 75/109.

Some doubt has been expressed about the relationship between the specific resistances of Brigand and Hobbit (WYR 14) (Priestley, Bayles and Crofts, 1981).

In 1982, isolate 77/26, which gave a high level of infection on Hobbit, also gave slightly higher infection on Brigand than did other isolates. The other control WYV 14 isolate, P75/27, gave only low infection and low positive residuals on both varieties. It seems likely that the resistances of the two varieties have something in common, but the extent of the similarity is not clear.

Maris Ranger, Maris Freeman and Kinsman, which were resistant to all isolates except 72/852 and 75/109 in seedling tests, also showed evidence of interaction with these isolates in adult plant tests (Box B), confirming their identification as WYR 6. Kinsman appeared to interact more markedly with isolate 75/109 than did the other two WYR 6 cultivars, suggesting that M. Ranger and Maris Freeman may possess additional resistance, the compatible virulence for which is absent from 75/109. This confirms observations first made by Priestley and Byford, 1977.

The high degree of similarity between WYR 6 cultivars M Ranger and M Freeman and the WYR 12 cultivar Mega appears to have been due to their common interaction with isolate 72/852 (Boxes B and C), which possesses both the corresponding virulences WYV 6 and WYV 12. Similar relationships for certain WYR 6 and WYR 12

cultivars were noticed by Priestley, Bayles and Crofts (1982). The adult plant interaction of Armada (WYR 12) with isolate 72/852 was also confirmed (Box C).

Clement, Stuart, Abele and Baron showed some susceptibility in seedling tests to isolates 81/34 and 81/A1, possessing WYV 9. The adult plant tests demonstrated that Abele and Baron possess additional adult plant resistance, for which there is currently no corresponding virulence.

Although Clement and Stuart were not closely linked by the multivariate analysis, both show increased infection levels with the control isolate WYV 9 76/15, and isolates 81/34 and 81/A1 (Boxes marked D). Residuals and infection levels suggest that 81/34 possessed increased virulence for Stuart compared with the other two isolates.

Eight isolates from the 1981 survey were tested. Isolates 81/14 and 81/11 were of the WYV 13 type, resembling 76/71. Isolates 81/37, 81/2 and 81/60 were similar to each other, possessing the overall virulences WYV 1,2,3, but showing no indication of specific adult plant virulence. Isolates 81/57 and 81/4 interacted with the WYR 14 cultivars M. Bilbo and Hobbit and therefore possessed WYV 14. Isolate 81/34 resembled isolate 81/A1 (a re-isolate from an inoculated plot of Clement), both being virulent on Clement and Stuart, as discussed above. There was no evidence from adult plant tests that any of the 1981 isolates possessed increased virulence for previously resistant cultivars or previously undetected combinations of virulences. To date no isolates have been found that possess virulence for more than one of the adult plant resistances WYR 11, 12, 13 or 14.

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Table 4 Results of adult plant tests 1982

Values are percent leaf area infection (mean of 4 assessme
Boxes are used to identify parts of the matrix and have no

Varieties and isolates are listed in the order of dendrogr

Cultivar	WYR Factors	Isolate	Mixture	77/26	76/15	80/32	81/14	81/11
		WYV Factors		1,2,3,14	2,3,4,8,9	1,2,3,13	1,2,3	1,2,3
Guardian	2,13		9R	6	5	13	6	10
M. Templar	1		7	13	3?	8	5	4
Prince	0		2R	6	2	7	3	1
Cappelle Desprez			2	5	3	7	3	0
Virtue	1,13		4	1	OR	7	2R?	5
M. Huntsman	2,13		4	1	0	9	2	1
Hustler	1,2,13		7	1	OR	7	5R?	3 A
Pageant	2, (13?)		4	0	0	5	5	1
Copain	13		2	0	0	4	3	1
M. Fundin			3	0	0	5	1	1
Brigand	2, (14?)		3	3	0	2	2R?	0
Norman	2,6		7R	OR	5R	OR	2R	OR
Stuart	9		2R	OR	3 D	OR	OR	OR
Aquila	var		0	0	0	0	0	0
Fenman	R		OR	OR	OR	OR	OR	OR
Stetson			OR	OR	OR	OR	OR	OR
Abele	9		OR	OR	OR?	OR	OR	OR
Baron	9		OR	OR	OR?	OR	OR	0
Avocet			OR	OR	OR	OR	OR	OR
Longbow	1,2,6		OR	OR	OR	OR	OR	OR
Flanders			1	2	0	0	1R	0
Galahad			2	3	0?	0	0	0
Rapier	2,4 (14?)		3R	OR	0	OR	OR	OR
Avalon	4		OR	OR	0	OR	OR	OR
Bounty	1,13		1	0	0?	1	1R?	0
Armada	12		1R	0	1	0	OR?	0
Mega	12		0	0	0	0	0	0
M. Ranger	6		3R	OR	1R	OR	1R	OR
M. Freeman	6		2R	OR	OR	OR	OR	OR
Kinsman	6		5R	OR	OR	OR	1R	OR
Tommy	7		2R	OR	3R	OR	OR	OR
M. Beacon	4		6R	OR	4	OR	OR	OR
Hobbit	14		8	8	0	0	1	0
M. Bilbo	14		22	22	4	6	4R?	5
Clement	9		3R	OR	24 D	1R	1R	OR
Michigan Amber	0		18	15	23	17	11	8

WYR Factors Identifications are based not o
(?) = provisional identificatio

WYV Factors ( ) = partially virulent on cor

Seedling reactions R = resistant (type 0-2)

nt dates)
statistical significance
ams given in Table 5.

76/71	81/37	81/2	81/60	75/27	81/57	71/493	81/4	72/852	75/109	81/34	81/A1
1,2,3,13	1,2,3	1,2,3(6)	1,2,3,(7)	2,3,4,14	1,2,3	1,2,3,7	1,2,3,(6),(7)	2,3,4,6,12	2,3,4,6	2,3,4,9	2,3,4,8,9
10	7	3	2	0	3	3	2	1	2	2	2
3	1	1	1	OR	2	3	2	1R	OR	OR	OR
2	0	0	0	1	0	0	1	2	1	1	2
2	1	0	0	OR?	0	2	2	5	3	1	2
2	0	0	0	OR	1	OR?	0	1R	OR	OR	OR
2	1	1	1	1	1	0	0	OR?	2	0	0
3	1	0	0	OR	1	0	0	OR	OR	OR	OR
3	0	2	0	0	0	0	0	0	2R?	0	0
4	1	0	0	OR?	2	0	0	0	1	0	0
3	0	0	0	0	2	0	0	1	OR	OR	0
1	0	0	0	1	1	0	1	OR?	OR?	1	0
OR	OR	OR	OR	OR	OR	OR	OR	0	1	OR	OR
OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	5R? D	2
0	0	0	0	OR	0	0	0	OR	OR	0	0
OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR
OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR
OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	0	0
OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	0	OR?
OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR
OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR	OR
0	0	0	0	0	0	0	1	0	OR	OR	1R
0	0	0	0	OR	0	0	0	OR	OR	OR	OR
OR	OR	OR	OR	1	OR	OR	OR	0	OR?	0	0
OR	OR	OR	OR	1R?	OR	OR	OR	1	0	0	0
0	0	0	0	OR	0	0	0	OR	OR	OR	OR
0	0	0	0	0	0	0	0	2 C	OR?	0	1
1	OR?	OR?	OR?	0	0	0	0	5	0	0	0
OR	OR	OR	OR	OR	OR	OR	OR	5	1	OR	OR
OR	OR	OR	OR	OR	OR	OR	OR	5 B	1	OR	OR
OR	OR	OR	OR	OR	OR	OR	OR	4	7	OR	OR
OR	OR	OR	OR	OR	OR	14	OR	OR	OR	OR	OR
OR	OR	OR	OR	3R?	OR	OR	OR	OR?	2	4	2
0	0	0	0	2R	2	0	2	1	0	0	0
3	0	0	0	8R?	8	1	8	3	3	3	2
OR	OR	OR	OR	0?	OR	OR	OR	OR	OR	22R? D	17
6	8	10	7	10	8	4	5	17	18	16	21

nly on results presented here, but also on others reported previously.
n. R = resistant to all isolates.

responding resistance.

. Reactions not marked R were susceptible.

BROWN RUST OF WHEAT

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

Welsh Plant Breeding Station, Aberystwyth

Fourty four samples of wheat brown rust were received in 1982. Isolates of Puccinia recondita were cultured from these samples and 40 were tested on seedlings under both a low and a high temperature regime. None of the 8 Triticale lines tested was resistant to all isolates and the resistance of some was expressed only at either the high or the low temperature regime. Isolate WBRS-82-31 was virulent on all Triticale lines but not on Clement (WBR-1). Virulence to cv. Sabre was detected in two isolates for the first time. Resistance that only expressed at either high or low temperature was observed in particular lines carrying specific Lr factors. Tests of adult plants in field isolation nurseries confirmed the adult plant resistance classification of a number of important cultivars. Virulence to cvs Virtue, Hustler and Rapier was not detected and these cultivars remain resistant in cultivation.

SEEDLING TESTS WITH 1982 ISOLATES

Forty four samples of wheat brown rust were received from a range of winter wheat cultivars, mainly from the wheat growing areas of eastern England. From these samples, forty isolates of Puccinia recondita were successfully cultured and tested. Tests were carried out using standard methods on seedlings of 9 differential cultivars.

Differential cultivar	
Clement	(WBR-1)
Maris Fundin	(WBR-2)
Norman	(")
Hobbit	(")
Sappo	(WBR-3)
Maris Halberd	(WBR-4)
Gamin	(WBR-6)
Sterna	(WBR-7)
Sabre	(WBR-7?)
Armada	(Susceptible)

In addition, cv. Thatcher backcross lines carrying resistance factors Lr1, Lr2a, Lr3, Lr3bg, Lr3ka, Lr9, Lr15, Lr19 and Lr24 were included together with 7 other lines carrying resistance factors which were received from Dr R.A. McIntosh, University of Sidney, Australia and numbered RAM-1 to -7. The set was completed by the inclusion of 8

Triticale breeding lines carrying unidentified factors for resistance to P.recondita and these lines were from Dr F.G.H. Lupton, Plant Breeding Institute, Cambridge.

All tests were repeated under two different post-inoculation environments; a low temperature regime (5-10° and 16 h photoperiod) and a high temperature regime (ca 20° and 16 h photoperiod).

Results

Virulence to WBR-1 in cv. Clement, which is derived from rye, was detected in 14 isolates. Virulence to line RAM-7 which carries a rye-derived resistance, designated ST-1 sel., was also detected but the pattern of response indicated that it differs from WBR-1. The Triticale lines were tested to only 21 isolates. No line was resistant to all isolates and some showed a temperature-sensitive response, where resistance was expressed only at either the low temperature (eg CWT 77/116/89) or the high temperature regime (eg 82 code 32). Different patterns of response were observed between the Triticale lines indicating different resistance factors. Pathogen isolate WBRS-82-31 was virulent on all Triticale lines but not on Clement.

Virulence to the temperature-sensitive resistance WBR-2 which is present in Maris Fundin, Norman and Hobbit occurred commonly (35 isolates).

The temperature-sensitive resistances in cvs Sappo (WBR-3) and Maris Halberd (WBR-4), which are effective at low temperatures only, were confirmed although virulence to both was again detected in a few isolates. Some isolates differentiated the two resistances.

Gamin (WBR-6) was susceptible to all isolates. No isolate was virulent on Sterna (WBR-7) at the high temperature, but 21 were virulent at the low temperature only and 13 were avirulent at both low and high temperatures. Sabre showed a similar pattern of response which supports the hypothesis that it too carries WBR-7 (Clifford et al., 1981) although two isolates (WBR-82-25 and -43) gave a high infection type at both temperatures and will be further tested in the 1983 isolation nurseries.

In the Thatcher Lr backcross lines, resistance conferred by Lr9 was effective against all isolates but to some it was only expressed at the higher temperature; the converse was true of Lr15. Seed stocks of these lines were limited and of varied germinability and so tests were incomplete. High temperature resistance only was also expressed in carriers of Lr1, Lr3 and Lr3bg whereas in RAM-5 (Lr30) compatibility varied with specific isolate and temperature.

ADULT PLANT TESTS WITH 1981 ISOLATES

Two isolation nurseries were grown at Plas Gogerddan WPBS in 1981-82 to obtain information on adult plant responses of 38 winter and 2 spring wheat cultivars. The two isolates used were:

WBRS-81-13	(WBV-1,3)
WBRS-81-14	(WBV-1)

These isolates differentiate the resistances in the spring cultivars Sappo (WBR-3) and Maris Halberd (WBR-4) in seedling tests.

Three replicates of each cultivar were grown in each nursery and the specific isolates were introduced by transplanting infected seedlings throughout the nurseries. Assessments of percentage infection and reaction type were made on three occasions.

Results

These are summarised in Table 1. Cultivars were grouped according to their known or purported resistance factors and the test results confirmed these groupings. Sappo (WBR-3) was susceptible to isolate WBRS-81-13 and resistant to WBRS-81-14 whereas Maris Halberd (WBR-4) was resistant to both. Mithras, Galahad and Sentry were susceptible to both isolates; they are related by breeding and their resistances would appear to derive from Hobbit (WBR-2). The resistance of cvs Virtue, Hustler and Rapier was effective against both isolates and virulence to these cultivars has not been detected to date by the survey.

REFERENCE

CLIFFORD, B.C., NAZIM, M., JONES, E.R.L., PRIESTLEY, R.H. & CROFTS, J. (1981). Brown rust of wheat. UK Cereal Pathogen Virulence Survey 1980 Annual Report, pp.33-41.

Table 1. Adult plant field reactions of wheat cultivars to specific isolates of Puccinia recondita tested in field isolation nurseries at WPBS 1982

Cultivar	WBR factor	Isolate WBRS-81-13 $\bar{x}$ (%)	WBRS-81-13 Flag (%)	WBRS-81-13 RT	WBRS-81-14 $\bar{x}$ (%)	WBRS-81-14 Flag (%)	WBRS-81-14 RT
Clement	1	11	19	4	16	25	4
Aquila	1	7	13	4	11	20	4
Stuart	1	3	7	4	10	23	4
Abele+	1	8/0	15/0	4	9/0	15/0	4
Baron	1	8	15	4	17	33	4
Fundin	2	14	28	4	12	25	4
Bilbo	2	3	5	4	1	1	1.3
Templar	2	6	11	4	7	14	4
Wizard	2	14	27	4	15	33	3
Norman	2	4	7	3,1	8	19	3,2
Hobbit	2	7	12	3,2	9	20	3,2
Mithras	2	10	18	4	8	13	4
Sentry	2	16	33	4	14	30	4
Galahad	2	16	32	4	14	32	4
Kinsman	2	2	3	On,1,3	4	8	1,2,3
Sappo	3	15	30	4	3	7	4
Halberd	4	2	5	On,1,3	0.3	1	On,1,3
Huntsman	5	32	50	4	26	47	4
Brigand+	5	29/0	47/0	4	23/0	43/0	4
Mardler	5	25	43	4	16	30	4
Gamin	6	0.3	1	3,1	0	0	
Sterna	7	0.3	0	3	Tr	0	3
Sabre	7	0	0		0	0	
Ranger	8	7	13	4,2	9	20	4,2
Avalon	9	0.5	1	3	0.5	1	3
Bounty	9	*2	0	2	*0.2	0	3
Sportsman	9	0	0		0	0	
Virtue	?	*Tr	0	3	*1	0	3
Hustler	?	0	0		0	0	
Rapier	?	0	0		0	0	
Copain	-	27	47	4	16	30	4
Prince	-	23	42	4	20	30	4
Armada	-	19	28	4	18	32	4
Flanders	-	26	40	4	18	30	4
Kador	-	25	43	4	22	43	4
Fenman	-	10	15	4	11	17	4
Longbow	-	19	37	4	13	23	4
MMG 7669/44/1/5/5	-	5	8	On,1,3	3	8	On,1,3
MMG 2171/4A	-	0.3	1	1,3	9/0	20/0	4
MMG 5570/10	-	7	15	4	13	19	4

*Infection on lower leaves only;
+Plant mixture;

Flag (%) = mean percent infection, 1 scoring date, 3 replicates, flag leaf only;

$\bar{x}$ (%) = mean percent infection, 3 scoring dates, 3 replicates, all leaves.

Rosemary A Bayles and R H Priestley

National Institute of Agricultural Botany

The increased virulence of isolate 80/21 for Avalon and Bounty was confirmed in adult plant tests.

Stetson resembled Clement & Stuart (WBR 1). Results confirmed that Abele and Baron possess the overall resistance WBR 1 plus an adult plant resistance, which is overcome by isolate 80/1. 80/1 also possessed virulence for Hobbit, Norman and Longbow. Kinsman and Guardian resembled Maris Ranger (WBR 8) in their interaction with isolate 77/9.

Methods

Seedlings and adult plants of 36 wheat cultivars were inoculated with 4 isolates of Puccinia recondita supplied by WPBS (Table 1). Seedling tests were carried out in controlled environment conditions (16 h day at 18°C, 8 h night at 11°C). Adult plant tests were in Polythene tunnels, using the technique developed for wheat yellow rust (Priestley and Byford, 1978). Plots were sown on 25 November 1981, inoculated on 30 March and 15 April 1982 and assessed for percentage leaf area infection on 18 June (GS 75), 25 June (GS 85) and 2 July (GS 86).

Table 1 Isolates used in adult plant tests

	Origin			
Code	Cultivar	Site	Region*	WBV Factors
74/11	Maris Fundin	Seale Hayne	SW	WBV 2
77/9	Maris Ranger	WPBS Nursery**	W	WBV 1,2,5
80/1	Brigand	WPBS	?	WBV 1,2,5
80/21	Avalon	Rosemaund	WM	WBV 2,9

* SW = South West; WM = West Midlands; W = Wales

** Plot inoculated with isolate 76/1

All isolates originally supplied by WPBS

Results

Table 2 gives infection levels on adult plants and seedling reactions in 1982 tests compared with corresponding results for the same isolates in 1979 and 1981. Results for 1980 have not been included because of high levels of Take-all in the tunnels that year (Clifford, Nazim, Jones, Priestley and Crofts, 1981).

The 1982 data suggest that Stetson resembles the WBR 1 cultivars Clement and Stuart in its pattern of seedling and adult plant reactions, with higher levels of infection produced by both isolates 77/9 and 80/1 (Box A). There is also support for the view that Aquila possesses WBR 1 at adult plant growth stages (Box A), although the resistance is ineffective in seedlings (Clifford et al 1982).

1982 results confirm the hypothesis, (Priestley & Crofts, 1982) that cultivars Abele and Baron possess WBR 1, expressed at the seedling stage, plus an additional adult plant resistance which is overcome by isolate 80/1 (Box B).

Maris Ranger, which possesses an adult plant resistance WBR 8 (Clifford, Nazim, Jones, Priestley and Crofts, 1981), showed increased infection with isolate 77/9. There is some indication that Kinsman and Guardian resemble Maris Ranger in this respect (Box C).

The report of increased virulence for Avalon and Bounty, possessed by isolate 80/21 (Clifford, Nazim and Jones, 1982), was confirmed (Box D). Avalon is extremely susceptible to this isolate and, with approximately 30% of the UK winter wheat acreage sown with this cultivar in 1982/83, there is a real risk that the virulence could rapidly become widespread.

The three cultivars Hobbit, Norman and Longbow appeared to interact

Table 2

Brown Rust of Wheat
Results of 1982 adult plant and seedling tests, compared with the same isolates tested in 1979 and 1981.

Values are mean percent leaf area infection (mean of 3 assessment dates)
Data for 1980 have been omitted because of poor infection in polythene tunnels.
R = resistant reaction at seedling stage

	Isolate	74/11			77/9		80/1		80/21
	Year of test	79	81	82	81	82	81	82	82
Resistance Factor	Cultivar								
WBR 1	Clement	1	1R	OR	9R	5R	20	6	OR
	*Aquila	1	0	0	3	2	5	4	0
	Stuart	OR	1R	2R	5R	4R	6	3	OR
	Stetson	.	.	OR	.	8	.	1	OR
(WBR 1+)	Abele	.	OR	OR	1R	0	8	3	OR
	Baron	.	OR	2R	0	0	9	16	OR
WBR 2	M. Fundin	.	13	22	11	1	8	3	27
	M. Bilbo	18	4	29	2	1	1	1	26
	M. Templar	4	4	11	4	5	11	3	4
WBR 5	M. Huntsman	2	0	1	4	1	12	7	1
	Brigand	2	2	1	6	5	2	1	2
WBR 8	M. Ranger	1	.	0	.	5	.	0	0
	Kinsman	0	0	0	1	2	0	0	0
	Guardian	.	0	0	1	4	0	0	0
WBR 9	Avalon	0	0	12	0	0	OR	OR	40
	Bounty	0	0	1	0	0	0	0	13
	Hobbit	1	0	0	1	0	4	1	0
	Norman	.	0	0	2	0	4	4	0
	Longbow	.	0	0	0	1	7	6	0
	Pageant	.	OR	OR	OR	CR	OR	OR	OR
	Avocet	.	.	0	.	0	.	0	0
	Hustler	0	0	0	0	0	0	0	0
	Rapier	.	1	0	0	0	.	0	0
	Virtue	1	0	0	0	0	OR	0	0
	Galahad	.	.	0	.	0	.	0	0
	Fenman	.	4	7	1	1	4	3	4
	Cappelle-Desprez	.	1	6	1	0	3	4	8
	Mega	.	2	15	1	0	2	0	6
	Flanders	3	2	10	3	1	4	0	6
	M. Freeman	1	3	8	2	2	3	2	11
	Armada	11	6	14	12	3	8	3	13
	M. Beacon	.	7	24	7	4	17	4	18
	Copain	9	31	26	6	2	5	7	18
	Prince	2	6	9	2	6	1	2	3
	Tommy	.	6	34	6	7	10	3	19
	Michigan Amber	27	17	70	22	25	21	19	34

A, B, C, D, E

* = specific resistance expressed at adult plant stage

with isolate 80/1, (Box E). Evidence elsewhere has suggested that Hobbit and Norman, like M.Fundin, M.Bilbo and M.Templar, possess the overall resistance WBR 2 (Clifford et al 1981). However, the two groups of cultivars differ clearly in the adult plant reactions shown here, particularly in their reactions to isolates 80/1 and 80/21. Isolate 80/1 apparently possesses increased virulence for the adult plant resistance of Hobbit, Norman and Longbow in addition to that of Abele and Baron.

Pageant was resistant to all isolates at seedling and adult plant stages and therefore possesses resistance for which virulence has not yet been detected.

The other varieties tested varied widely in their average susceptibility but showed no evidence of specific resistance.

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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 continuing trend towards an increase in combined pathogenicity for BMR 3 and 4, and for BMR 4 and 5, presumably due to increased cultivation of cultivars with those resistance factors combined. The pathogenicity combination BMV 4+6 and 5+6 continued to occur at lower than expected frequencies. Pathogenicity for BMR 6+Ab (cvs. Triumph and Tasman) again increased, though not on non-corresponding hosts.

A survey was made of spore populations obtained directly from plots at NIAB regional trial centres. The patterns of population structure were closely similar to those obtained in the conventional surveys, but there was evidence of variation between sites. There was also evidence for variation in pathogenicity for spring cultivars in pathogen populations selected on winter cultivars.

WIST surveys of pathogenicity revealed an over-representation of BMV 5 in the ground surveys, and a considerable difference between the high frequency of pathogenicity for BMR 6+Ab in the atmosphere compared with the low values detected in populations on many cultivars in the ground surveys.
WIST surveys of fungicide insensitivity showed an increase in triazole-insensitivity in England, and a decrease in Scotland, in 1982 compared with 1981. The increase in England occurred both at low and high levels of insensitivity. Although cross-insensitivity occurred for a number of triazole-fungicides, occurrence of insensitivity to the triazoles and to ethirimol appeared to be independent.

Interactions of fungicide-insensitivity and pathogenicity characters were confirmed. Triazole-insensitivity was positively correlated with BMV 3, and negatively with most other BMV characters. Ethirimol-insensitivity remained in association with pathogenicity for BMV 5.

In the conventional survey, fewer isolates were received and processed than in 1981-2 because of the increased emphasis on alternative methods of sampling, either by using the WIST or by plot spore sampling, and on testing population samples for fungicide insensitivity. The range of samples received is summarised in Table 1; no new or unusual resistant gene combinations were found, although the nature of resistance of cv. RPB 9002 has yet to be confirmed. Incorrectly in last year's report, the cv. Regent was placed in BMR 2+3: subsequent tests and survey data confirmed that it probably belongs to group BMR 2+4+5. Cultivar Kym appears to comprise two

lines, one in BMR 2+4, and the second in BMR 4+8. Although isolates obtained from cv. Atem appear to be specific in that they are often pathogenic on BMR 4, there is yet no evidence for an increase in pathogenicity on this cultivar.

Pathogenicity for cv. Triumph was again higher than in previous years, and, as in the previous two years, it appears to be associated with pathogenicity for BMR 3. This implies that there is some relationship between BMV 3 and pathogenicity for the second resistance gene in cultivar Triumph, derived from Ab12.

Population structure and dynamics

Results from the conventional survey are given in Table 2; the set of test cultivars used was the same as in 1981.

Table 1. Number of samples received in 1982 and the BMR group definitions of the cultivars from which they were collected

BMR group	gene	Cultivar and number of samples
0	-	Golden Promise (47 fungicide treated, 5 untreated) Maris Otter (5) Halcyon (3)
1	M1h (2 genes)	Igri (3 fungicide treated, 4 untreated) Athene (5) Hydra (5) Pirate (5) Marko (4) Sonja (3) Gerbel (3)
2	M1g (2 genes)	Fenella (3)
3	M1a6	Midas (2 fungicide treated, 5 untreated) Carnival (4)
4	M1v (2 genes)	-
5	M1a 12+?	Medallion (3)
6	M1a7+M1k	Ark Royal (1)
7	M1a	-
8	M1a9+M1k	-
1+2		Tipper (4)
2+4		Golf (6) Koru (1 fungicide treated, 2 untreated) Georgie (1)
2+5		Athos (7) Nicole (4) Patty (1)
2+4+5		Regent (5)
3+4		Goldmarker (1 fungicide treated, 4 untreated)
4+6		Claret (1)
4+8		Kym (1 fungicide treated, 7 untreated)
6+Ab		Triumph (3 fungicide treated, 24 untreated) Tasman (6)
4+?		Atem (3)
unknown		RPB 9002 (1) ? (1)

Table 2. Mean pathogenicity of bulk isolates on test seedlings of BMR group cultivars

BMR group	Source of isolate	No. of Isolates	BMV group of test seedlings 2	3	4	5	6	7	8	3+4	4+5	4+6	6+Ab	4+?
0	Golden Promise, untreated	4	49	85	34	21	6	0	0	24	8	0	9	0
	" " Baytan treated	2	22	60	4	6	3	0	0	0	2	0	0	0
	" " Bayleton treated	9	19	49	8	9	6	0	0	1	3	0	4	0
	" " Bardew treated	5	51	62	12	19	31	0	0	5	3	0	2	0
	" " Radar treated	5	36	76	7	7	5	0	0	6	1	0	1	0
	" " Corbel treated	3	45	59	20	32	18	1	0	4	12	0	16	0
	" " Calixin treated	1	68	85	13	21	0	0	0	9	4	0	1	0
	" " Baytan + Tilt	1	13	3	0	32	0	66	0	0	0	0	2	0
	" " Mistral + Corbel	1	66	100	0	19	0	0	0	4	0	0	2	0
	Halcyon	1	60	13	7	51	0	0	0	1	1	0	0	0
1	Igri	2	36	38	28	34	13	0	0	5	30	0	0	0
	Gerbel	2	87	45	42	56	17	0	0	7	9	0	5	0
	Sonja	1	67	0	60	84	0	0	0	0	39	0	0	0
	Hydra	4	49	69	34	54	23	2	0	20	16	0	6	0
	Pirate	3	21	86	15	8	11	0	0	11	3	0	1	0
	Marko	3	46	61	33	33	22	4	0	26	16	0	20	0
	Athene	2	18	60	26	5	2	1	0	21	8	0	3	0
2	Fenella	3	69	19	68	64	12	0	4	4	41	0	3	0
3	Midas	1	18	60	0	1	11	0	0	0	0	0	0	0
	Carnival	1	68	100	75	18	24	0	0	65	20	0	19	0
1+2	Tipper	2	48	48	27	23	18	0	0	24	0	0	0	0
2+4	Golf	2	84	27	78	78	0	32	0	17	63	0	1	0
	Koru	1	79	4	104	1	0	0	0	0	0	0	5	0
2+5	Athos	2	48	16	37	66	15	0	0	16	34	0	0	0
3+4	Goldmarker	2	40	77	77	6	0	0	0	60	12	0	4	0
4+5	Regent	1	44	17	65	95	13	0	0	16	36	0	0	0
4+8	Kym, untreated	1	47	73	85	37	0	0	0	58	23	0	1	0
	Kym, Baytan, Bayleton	1	34	120	107	0	0	0	0	69	0	0	0	0
4+?	Atem	1	61	0	74	72	0	0	0	0	75	0	0	0
6+Ab	Triumph	12	64	70	3	7	80	0	0	4	1	1	77	0
	Tasman	2	73	95	2	0	102	0	0	6	0	2	102	0

Table 3. Values for non-corresponding pathogenicity for each of the years 1978-82

Year	BMV characters 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

1982a - conventional survey samples
1982b - plot spore samples from NIAB regional centres

The data from the conventional survey samples were characterised by a decrease in BMV 2 and 6, and an increase in BMV 3 and 4. However, of the relatively small number of samples tested, a larger proportion than usual were from Scotland and the North, where BMR 3 had tended to be more common and BMR 6 less so, than further south, for a number of years. This is reflected in the data (Table 3, 1982b) obtained from plot spore samples (see below) collected from NIAB Regional Trials. The latter samples contained a higher frequency of BMV 2 and, particularly, BMV 5, and a lower frequency of BMV 3, than those from further north.

Values for non-corresponding pathogenicity among samples obtained from a number of BMR groups were calculated and then averaged for the past three years (Table 4) for comparison with the data previously presented for the years 1978-80 (1980 report, Table 6, page 53)

The most notable changes were increases in BMV 3, 4 and 5 on BMR 1 (winter barleys) and BMR 6 cultivars, in BMV 4 on BMR 3, and BMV 5 on BMR 4. These changes were probably due largely to increased cultivation, susceptibility and sampling from cultivars with combined resistances such as cv. Goldmarker (BMR 3+4) and cv. Egmont (BMR 4+5). The general decline in BMV 6, indicates the widespread use of cv. Triumph. Although this cultivar has BMR 6+Ab resistance, it has not yet become widely susceptible, and pathogenicity for Triumph appears to be generally uncommon on all other cultivars. Furthermore, population samples from BMR 6 cultivars often do not show a high level of pathogenicity for cv. Triumph.

The combinations of BMV 4 and 6, and of 5 and 6, have occurred at lower than expected frequencies for a considerable number of years, which has contributed to the success of a number of cultivar mixtures based on components selected from the matching BMR groups.

Table 4. Values for non-corresponding pathogenicity in samples from a number of BMR groups averaged for two groups of years, 1978-80 and 1980-82

BMR group		BMV characters 2	3	4	5	6
0	1978-80	67	41	19	28	33
	1980-82	64	49	23	25	24
1	1978-80	67	23	13	21	42
	1980-82	59	35	27	25	21
3	1978-80	63	-	20	33	32
	1980-82	54	-	29	23	24
4	1978-80	61	22	-	23	3
	1980-82	77	19	-	37	3
6	1978-80	74	20	5	15	-
	1980-82	78	40	9	18	-

Spore population samples

Conventional methods of sampling the pathogen by taking a few leaves or leaf pieces may not adequately sample the whole population of the pathogen selected on a plot or field of a particular cultivar. A simple device is now used, therefore, to collect large random samples of spores on to seedlings of the susceptible control, cv. Golden Promise. The device consists of a small wire cage, to hold and protect the seedlings, mounted on a handle. The cage was dragged through the centre of plots of winter and spring barley cultivars in Recommended List Trials at NIAB Regional Centres. The summarised data obtained from the samples maintained on cv. Golden Promise, and tested on the standard differential cultivars, are given in Table 5.

As suggested above (Table 3), the general pattern follows that obtained in previous years, with the observed increases reflecting the increased sampling from cultivars with combined resistances. The pattern of interaction of pathogenicity characters also follows the previous data (e.g. Table 4) in that the values for BMV 4 and 5, and their combinations, are lower than expected on BMR 6 and 6+Ab, as is BMV 6 in samples from all cultivars with BMR 4 and 5 in various combinations.

Table 5. Pathogenicity values for spore populations obtained by direct sampling of winter and spring barley plants at NIAB regional trial centres

BMR group	BMV characters 2	3	4	5	6	7	3+4	4+5	6+Ab
0	64	39	31	53	21	5	7	30	7
1	52	39	25	49	18	7	9	19	9
3	59	63	36	36	25	8	29	20	11
6	64	43	11	22	80	1	8	9	18
2+4	62*	17	53	64	2	1	12	44	2
2+5	70	12	51	83	6	3	4	47	3
3+4	53	69	67	27	1	1	79	37	3
4+5	57	10	60	83	1	1	8	59	3
6+Ab	60	43	13	19	69	1	6	9	79
means for non-corresponding pathogenicity	59	29	28	39	10	3	11	27	7

* underlined values are corresponding pathogenicity values.

It is interesting to note the similarity of pathogenicity profiles in the samples from BMR 6 and 6+Ab (cv. Triumph). However, although BMV 6 has a high value in samples from BMR 6+Ab, presumably because BMV 6+Ab evolved from BMV 6, BMV 6+Ab has a relatively low value (18) in samples from BMR 6 cultivars.

The data from which Table 5 was derived can be grouped to examine the variation between regional trials since the range of cultivars sampled was approximately the same at each site (Table 6).

Table 6. Non-corresponding pathogenicity values for spore populations obtained by direct sampling of winter and spring barley plots at NIAB regional trial centres

Site	BMV characters 2	3	4	5	6	7	3+4	4+5	6Ab
Morley	60	18	20	31	7	1	8	19	3
Terrington*	43	45	17	35	27	3	11	12	18
Headley Hall	48	40	20	30	16	1	13	26	4
Wye	50	30	26	33	14	3	10	23	8
Sutton Bonington	67	26	30	47	9	4	12	19	6
Cambridge	65	33	34	43	7	0	10	36	5
Sparsholt	60	30	38	52	11	7	10	41	5
Mean†	58	30	28	39	11	3	11	27	5

* winter barley cultivars only. † excluding Terrington data

The values for Morley were unusual in that the majority were lower than elsewhere; there is no obvious explanation for this observation. Among the other sites, there was variation in the frequency of pathogenicity

characters BMV 4 and 5, and thus 4+5, showing a correlated increase from the top to the bottom of the table. Less obviously, there was a tendency for BMV 6 to decrease as BMV 4 and 5 increased. Overall, it is likely that cultivar assessments may reasonably reflect field performance since average pathogenicity values, except for BMR 6+Ab, are similar to the general pattern in the air spora (see WIST data below). Data from an individual site may be misleading, however, depending on the bias of the pathogen population at that site towards, or away from, BMV 4 and 5.

WIST: sampling the air spora

Sampling the general air spora for pathogenicity characters was less comprehensive than in the previous two years because of the concentrated use of the WIST system for sampling for fungicide insensitivity. The limited data produced (Table 7) did however, illustrate several important points.

Table 7. Pathogenicity values obtained from WIST samples in England and Scotland, compared with non-corresponding pathogenicity values obtained by plot spore sampling and conventional survey sampling

	BMV characters							
	2	3	4	5	6	3+4	4+5	6+Ab
WIST England	57	42	30	45	35	6	21	37
Scotland	47	54	31	11	19	48	3	10
Plot spore samples	58	30	28	39	11	11	27	5
Survey samples	48	43	28	23	9	16	17	4

Compared with the previous year (1981 report, Table 5, p 43) in England, there was an increase in BMV 3 and 5 and a decrease in BMV 2 and 4, probably reflecting a changing response to the cultivars and fungicides currently in use. The WIST data for Scotland differ from those for England, with higher values for BMV 3 and 3+4 (due to the relatively large area of cv. Midas, BMR 3) and low values for BMV 5, 4+5, 6 and 6+Ab due to the lesser use of BMR 5, 6 and 6+Ab in the north than in the south. The difference between the two WIST surveys is reflected in the two types of plot survey. The WIST data for England closely match the mean data for the survey of plot spore samples except for BMV 6 and 6+Ab, whereas the Scottish WIST data are more closely matched by the data from the conventional survey samples, again with the exception of BMV6 and 6+Ab. There differences presumably occur because the plot spore samples were obtained exclusively from England, with a bias to the south, whereas the conventional survey was over-represented by samples from Scotland. It may

be noted from Table 6, that the most northerly of the NIAB centres, Headley Hall, also produced a relatively high value for BMV 3, and low for BMV 5.

Although generally similar, there was a consistently large difference between the WIST and the ground surveys, in that BMV 6 and 6+Ab always had larger values in the aerial surveys. This indicates that the corresponding cultivars were producing relatively large quantities of spores in commercial cultivation, reflected in the WIST catches, but that the pathogenicity characters occurred at lesser frequencies in combination with other BMV characters on non-corresponding hosts.

It is also possible that the low values for BMV 6 and 6+Ab in plot survey samples could have occurred because of under-representation of the corresponding cultivars in trials compared with commercial cultivation. If so, this explanation is likely to provide only part of the answer, because it is clearly evident from Tables 5 and 9, that these two pathogenicity characters do occur at only a low frequency in pathogen populations on cultivars with, for example, BMR 4 or 5 resistance.

Because of the current interest in the erosion of mildew resistance on cv. Triumph, seedlings of this cultivar and cv. Tasman, which has similar BMR 6+Ab resistance, were exposed in a number of WIST journeys. Values for pathogenicity on these two cultivars, relative to cv. Golden Promise, and obtained directly in the WIST, are presented in Table 8.

Table 8. Pathogenicity values on cvs. Triumph and Tasman (BMR6+Ab), relative to cv. Golden Promise, in WIST samples from different areas

Area	Pathogenicity on cv. Triumph	Tasman
Midlands	45	54
N. England	29	28
S. Scotland	19	18
Mid & N. Scotland	12	7

Values for the two cultivars were closely correlated, were relatively high in the south, and declined northwards. The degree of pathogenicity apparent in the southerly exposures indicated that this resistance is now under considerable pressure from the pathogen. Clearly, however, this pressure must be offset to a considerable extent by the poor survival of BMV 6+Ab on other cultivars (Table 5) and particularly on winter cultivars (see BMR 1 in Table 5, and Table 10 below). Poor survival is further illustrated by data obtained by testing WIST samples, obtained at different dates on cv. Triumph and Tasman, on the standard test cultivars (Table 9).

Table 9. Mean pathogenicity values on test seedlings of WIST samples collected on different dates on cvs. Triumph and Tasman in eastern England

WIST Date	BMV characters							
	2	3	4	5	6	3+4	4+5	6+Ab
10 June	74	44	0	2	65	3	0	49
23 June	65	59	5	0	70	3	0	80.
30 June	69	59	5	9	72	3	1	55
15 September	36	43	3	9	50	6	1	35

The data in Table 9 show clearly the low pathogenicity for BMR 4 and 5 in the BMR 6+Ab samples. They also show the high value for BMV 3, noted for the previous two years. The relatively low value for BMV 6+Ab itself in September may already reflect selection against this character during the oversummering and early autumn periods. The reason for the low value of BMV2 in September is not known.

Winter barleys

The mean pathogenicity profiles for a range of winter barley cultivars are given in Table 10a to compare the conventional and plot spore survey methods. The results are closely similar and the minor differences probably reflect, again, the geographical origins of the data in the two surveys (see Table 7). Comparing the overall values with those obtained from spring cultivars (see Tables 5 and 6), there is a tendency for BMV 5 to survive better on winter cultivars, than on spring cultivars as a whole.

From Table 10b, it is evident that winter barley cultivars in BMR 0 and BMR 1, together with Fenella (BMR 2) produced closely similar profiles. Pathogenicity for BMR 6 was relatively low on all of these cultivars, but was nevertheless twice as high as that for BMR 6+Ab, confirming the relatively poor degree of overwintering survival of pathogenicity for cv. Triumph on winter barley.

The cultivar Tipper (BMR 1+2) showed selection for the matching pathogenicity BMV 2, but was otherwise similar to cv. 5206EH; both appeared to support relatively high frequencies of several pathogenicity characters. Cv. Medallion also supported high frequencies of BMV 4, and particularly, BMV 5, reflected in high frequency of the combined pathogenicity, BMV 4+5. On the other hand, cvs. 493DH and Athene, both supported low frequencies of BMV 4 and 5 (and thus, of BMV 4+5); this feature of cv. Athene had been noted in previous years.

Table 10. Pathogenicity profiles in pathogen population samples taken from winter barley cultivars. a) comparison of profiles for BMR 1 samples in the conventional and plot spore surveys, b) comparison of BMR 0 and 1 winter cultivars with each other and with new cultivars

a)

	BMV character								
	2	3	4	5	6	7	3+4	4+5	6+AB
conventional survey	50	45	31	46	12	1	10	16	5
plot spore survey	50	35	27	53	16	8	9	20	9

b)

BMR group or cultivar	2	3	4	5	6	7	3+4	4+5	6+AB
BMR 0	60	41	27	52	23	4	6	25	8
BMR 1	50	35	27	53	16	8	9	20	9
cv. Fenella	64	31	26	56	21	5	12	23	9
cv. Tipper	80	37	53	53	25	10	9	22	17
cv. 5206EH	48	43	57	83	44	11	18	15	16
cv. Medallion	66	19	44	72	11	5	9	52	9
cv. 493DH	58	52	20	23	18	7	12	14	28
cv. Athene	34	55	8	10	20	5	6	2	11

The differences between winter cultivars in the pathogen populations that they supported are of potential interest in considering diversification between winter and spring crops, but they are likely to be small in relation to the absolute size and variation of pathogen populations generated on winter barley cultivars, since only one, cv. Athene, is regarded as highly resistant to the disease.

Fungicide insensitivity

The WIST survey of fungicide insensitivity was continued in 1982 in a similar way, but on a larger scale, to that in the previous year. An overall comparison of insensitivity to the triazole fungicides is given in Table 11, which gives the colony numbers on treated cv. Golden Promise seedlings (i.e. 0.025 g. a.i. triadimenol) relative to those on untreated cv. Golden Promise seedlings for the past two years in England and Scotland.

Insensitivity appears to have increased in England, and decreased in Scotland, to the extent of causing a change in ranking for the two countries. Within Scotland, there was also some variation; in the south east of the country the insensitivity value was 37, and in central Scotland, 35, whereas north and west of Aberdeen, it was 51.

Table 11. Average numbers of colonies on seedlings of cv. Golden Promise treated with 0.025 g a.i. triadimenol per kg seed, relative to those on untreated seedlings, in England and Scotland in 1981 and 1982

	1981	1982
England	38	51
Scotland	63	43

Laboratory tests of the samples obtained in the WIST on cv. Golden Promise seedlings treated with different amounts of triadimenol confirmed the direct observations (Table 12).

Table 12. WIST samples of powdery mildew obtained on treated seedlings of cv. Golden Promise and tested in the laboratory on leaf segments of further seedlings treated with different amounts of triadimenol

		Seedling test dose (g a.i. per kg seed)				
Origin	Year	0.04	0.08	0.125	0.250	0.375
England	1981	39	14	3	0	0
	1982	74	41	12	2	1
Scotland	1981	91	38	11	3	0
	1982	88	52	10	1	1

In the English samples, there appears to have been an increase in insensitivity at all levels, whereas for the Scottish observations, the populations seem to have been more insensitive at low levels, with no increase at high levels. Within the range of Scottish observations, there was a tendency for the populations in the south east to maintain a higher frequency of more insensitive genotypes than in the north, despite the lower overall level of insensitivity. Several individual isolates collected in 1982 were more insensitive than the standard control isolate obtained by Dr J..T. Fletcher in Northumberland in 1980.

A number of additional observations, including field tests by Ms L. Antill (an M. Phil. student), laboratory tests, and comparisons of direct and indirect tests of WIST material, all pointed to the reduced fitness (reproduction) of isolates trapped on seedlings grown from seed treated at 0.075 g a.i. triadimenol compared with those trapped on untreated seedlings, when both were grown on untreated seedling leaf segments. The difference on untreated seedling leaf segments was considerably less obvious between isolates trapped on seedlings grown from seed treated at 0.025 g a.i., and those from untreated seedlings. However, isolates

trapped from seedlings treated at 0.075 g a.i. tended to become more insensitive when maintained on treated seedlings. Thus the method of maintenance of the isolates for indirect testing may affect the results obtained. A conservative approach was followed by maintaining all isolates on untreated seedling leaf segments. The results given for indirect tests therefore tend to underestimate the frequency and level of fungicide insensitivity that actually occurred when the isolates were trapped.

The English data were averaged from a number of WIST collections made at intervals from March 1982 onwards. The trend of insensitivity with time is summarised in Table 13, and shows a tendency towards an increase in insensitivity apparent in the counts made on exposed seedlings treated at both levels of triadimenol. Simple linear regression analysis of the increase with time shows that the slopes for both concentrations are highly significant (0.025 g a.i. dose, 3.6% per month, $P<0.001$; 0.075 g a.i. dose, 1.6% per month, $P<0.001$). Subsequent progress of the insensitive fraction of the pathogen population will depend on usage of the triazole fungicides, but it may also be affected by cultivar interactions (see below).

Table 13. Colony numbers on treated (0.025 and 0.075 g a.i. triadimenol per kg seed) relative to untreated seedlings of cv. Golden Promise exposed in WIST in 1981 to 1983

	1981	1982		1983	
Dose (g a.i. per kg seed)	0.025	0.025	0.075	0.025	0.075
January				130	24
February				52	28
March	8	28	-	104	40
April	10	48	17		
May	16	36	12		
June	26	48	19		
July	39	42	17		
August	-	-	-		
September	-	78	78		
October	-	77	64		
November	25	73	18		

The compound triadimenol has been used generally for experimental tests but other experiments at PBI, RES and in ADAS, have shown that cross insensitivity occurs at least between triadimenol, triadimefon, propiconazole, prochloraz, triforine and triminol. There is no cross insensitivity with ethirimol, but the relationship between the triazoles and morpholines with respect to insensitivity is not completely resolved.

For the moment, it appears reasonable to regard the triazoles and morpholines as different fungicide groups from the point of view of fungicide diversification. Tests of WIST samples of mildew obtained from seedlings either untreated or treated with triazoles or morpholines, and inoculated on the standard differential cultivars, each produced different pathogenicity profiles. This may be some further indication of a lack of cross insensitivity, but it was not possible to gauge accurately the degree of insensitivity of any of the isolates to morpholine fungicides.

Many isolates with partial insensitivity to ethirimol have been found including some that were also insensitive to the triazoles, and some that were not. There was an indication, amongst a limited number of observations, that isolates with combined insensitivity were not as insensitive to either fungicide group as those insensitive to only one of the groups.

The positive association of triazole-insensitivity with pathogenicity for BMR 3, noted previously, was confirmed in 1982. Correlation tests were made between the frequencies of pathogenicity characters obtained in WIST samples and the seedling treatment from which each was obtained (i.e. untreated, 0.025, or 0.075 g a.i.), and between the frequencies of pathogenicity characters and the fungicide insensitivity values obtained indirectly, by subsequent tests of each trapped isolate in the laboratory on a range of seedlings treated with different doses of the fungicides (Table 14).

Table 14. Correlations of the frequency of BMV characters with fungicide insensitivity in direct and indirect tests of pathogen isolates obtained in the WIST in East Anglia in 1982 (March-June)

	BMV character					
Test	2	3	4	5	6	6+Ab
Direct	-0.99	+0.30	-0.19	-0.88	-0.97	-0.78
Indirect	-0.23	+0.30	+0.02	-0.34	-0.32	-0.22
P*	n.s.	0.05	n.s.	0.05	0.05	n.s.

* p values refer to indirect tests only

In Table 14, significance values for the correlation coefficients in the direct tests were not calculated since they were based on only three fungicide levels (0, 0.025 and 0.075 g a.i.). However, the pattern of positive and negative correlations was similar to that obtained with the indirect tests, each of which was based on 57 isolates and an insensitivity index derived from tests with seven fungicide treatments.

BMV 3 was the only character that showed a correlation that was both

positive and significant. The remainder were more or less negatively correlated, particularly BMV 5 and 6. Because of the decrease in insensitivity of the stored isolates before the indirect tests, it is likely that the correlation coefficients obtained in the direct tests may be closer to the real situation in the field. It appears therefore that continued cultivation of certain resistant cultivars, particularly those with BMR 5 and 6, may be helping the durability of the triazole fungicides.

In a field trial in 1982 comparing the performance of triadimenol and ethirimol fungicides on BMR 3 and BMR 5 cultivars, there was a significant interaction in mildew control. The disease on the BMR 3 cultivars was controlled more by ethirimol than by triadimenol, whilst the reverse was true for the BMR 5 cultivars. This interaction was also apparent, though to a lesser extent, in the yields obtained (Wolfe, Minchin & Slater, Ann Rep PBI Cambridge for 1982; in press). It seems clear, therefore, that current levels of insensitivity are of some economic importance in terms of fungicide effectiveness.

The only other explanation for these observations would involve the hypothesis that the resistance genes in the cultivars differentially affected uptake of the fungicides, which seems unlikely.

From the data obtained, together with other survey and field trial data, a Table of fungicide-cultivar interactions can be constructed, which is relevant both to diversification, and to integrated disease control (Table 15).

Table 15. Interaction of BMV groups and insensitivity to some major fungicides

	Triazole fungicides	Ethirimol fungicides
BMV 3	+ve correlation	no correlation
BMV 5	-ve	+ve correlation
BMV 6	-ve correlation	-ve correlation
Other BMV gps	-ve correlation	no correlation

Thus, from Table 15, triazole fungicides will be least effective if used on BMR 3 cultivars, and, probably, most effective on cultivars from BMR 5 and 6. Ethirimol, on the other hand, will be least effective if used on BMR 5 cultivars, but most effective on BMR 6 cultivars. With the triazole fungicides, a complication arises with respect to BMR 6+Ab, i.e. cultivars such as Triumph and Tasman. On the one hand, these cultivars possess BMR 6, which increases the potential effectiveness of applied triazoles, but on the other hand, it has now been observed for three years that they also

select for BMV 3 (see Table 5), which tends to decrease the potential effectiveness of those fungicides. From Table 14, the consequence appears to be that the triazole fungicides may be less effective on BMR 6+Ab cultivars than on those with BMR 6 alone.

YELLOW RUST OF BARLEY

Rosemary A Bayles and R H Priestley

National Institute of Agricultural Botany, Cambridge

Seedling virulence tests with 1982 isolates showed that the frequency of virulence for Bigo (BYR 2) has increased to nearly 100%, while virulence for Astrix (BYR 1) remains at 100%. Adult plant tests confirmed that Triumph, Tasman and Carnival possessed resistance effective only at the seedling stage. Cultivar x isolate interactions detected in the 1981 adult plant tests were not apparent in similar tests in 1982.

INTRODUCTION

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

Table 1. Resistance factors to P. striiformis

BYR factor	Test cultivars	Type*	Year virulence detected
BYR 1	Astrix	overall	1960
BYR 2	Bigo, Varunda	overall	1972-5
	Mazurka	seedling	

* Sensu Zadoks (1961); overall resistance is effective at all growth stages, seedling resistance is ineffective at adult plant growth stages.

VIRULENCE TEST METHODS

The methods used were similar to those described for wheat yellow rust by Priestley (1978).

Seedling tests with 1982 isolates

A total of 37 samples was received during 1982. This was less than half the number received in 1981 and reflects the relatively low incidence of yellow rust of barley in 1982. The samples had been collected in a non-

random way from Athene (4 samples), Atem (4), Igri (3), and 24 other cultivars. 21 samples were from winter cultivars and 15 samples from spring cultivars. Isolates were cultured from 25 samples; the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Berac. Virulence tests were carried out on all 25 isolates.

Adult Plant tests with 1981, 1980 and control isolates

Tests to measure the virulence of P. striiformis isolates on adult plants of spring barley were carried out using the polythene tunnel method developed for wheat yellow rust (Priestley and Byford, 1978). Details of the isolates, which included four from 1980 being tested in tunnels for a second year, are given in Table 2. Four replicate tussocks of 18 cultivars were sown on 25 March 1982, inoculated on 7 May and assessed for percentage leaf area infection on 21 May (GS 37), 4 June (GS 58) and 18 June (GS 80).

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

Code	Cultivar	Region*	Site	V Factors
74/33	Malta	N	Morpeth	BYV 1
75/101	Varunda	YL	Boroughbridge	BYV 1,2
80/32	Porthos	WM	Rosemaund	BYV 1,2
80/47	Erna	S	Berwick	BYV 1
80/80	Dragon	SW	Seale Hayne	BYV 1,2
80/129	Triumph	EM	Weston Upon Trent	BYV 1,2
81/7	Igri	W	Clwyd	BYV 1,2
81/31	Tintern	N	Cockle Park	BYV 1,(2)
81/44	Athos	N	Houghall, Durham	BYV 1,2
81/49	Video	SW	Seale Hayne	BYV 1

* N, Northern; YL, Yorks and Lancs; WM, West Midlands; S, Scotland; SW, South Western; EM, East Midlands; W, Wales.

() = partially virulent on corresponding resistance.

VIRULENCE TEST RESULTS

Seedling tests with 1982 isolates

Sampling was not random and therefore the virulence frequencies for 1972-1982 (Table 3) should be interpreted with care. Nevertheless, it is clear that the increase in frequency of BYV 2 from 1977 onwards has continued, with

96% of isolates tested in 1982 possessing this virulence. This trend is surprising in view of the rarity of the corresponding BYR 2 resistance in barley cultivars; the area of Mazurka (BYR 2) has now fallen to about 1% and none of the currently widely grown barley cultivars possesses BYR 2.

Table 3 Virulence factor frequency (%)

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

Adult plant tests with 1981, 1980 and control isolates

Average disease levels (mean of 3 assessments) and seedling test reactions are given in Table 4. A multivariate analysis of the data was carried out (as described by Priestley and Byford, 1979) and Table 5 gives 2-factor residuals and the corresponding cultivar and isolate dendrograms derived by average linkage cluster analysis.

The cultivars Triumph, Tasman and Carnival, which were closely linked by the cultivar dendrogram, were resistant to most isolates at the seedling stage, but were moderately infected as adult plants. 'Seedling' resistance, effective at seedling stages but not at adult plant stages, has previously been reported for the cultivar Mazurka (Priestley & Byford, 1979). Nicole, Regent and Patty were seedling resistant to some isolates, but seedling reactions appeared to bear little relationship to adult plant infection levels.

There was some indication from residuals (Table 5) that the cultivar Golf, in these tests for the first time, interacted with isolate 80/47.

Table 4

Yellow rust of barley

Results of adult plant tests 1982

Values are mean percent leaf area infection (average of 3 assessment dates)

R = resistant reaction in seedling test. (Absence of R = susceptible).

	Isolate	80/47	80/129	75/101	80/32	74/33	80/80	81/31	81/49	81/7	81/44
	BYV Factors	1,2	1,2	1,2	1,2	1	1	1(2)	1	(1)2	1, 2
Cultivar	BYR Factors										
Goldmarker	0	3	6	6	2	6	3	0	3	1	2
Triumph	Rx	4 R	5 R	5 R	3 R	5	4 R	2 R	3 R	2 R	3 R
Tasman	Rx	2 R	2 R	2 R	1 R	2 R	1 R	0 R	1 R	0 R	1 R
Carnival	Rx	2 R	2 R	4 R	2 R	3 R	1 R	1 R	3 R	0 R	2 R
Nicole	?	2	3	5	1	2	1 R	0 R	2 R	0 R	1
Regent	?	3	3	6	1 R	2	2 R	0 R	1 R	0 R	2
Patty	?	2	4 R	1	0 R	1 R	1 R	0	1 R	0 R	1
Bigo	2	1	3	4	2	0 R	0 R	0 R	1 R	1	2
Varunda	2	7	10	10	4	6 R	4 R	1 R	2 R	2 R	5
Kym	0	8	9	14	7	10	5	2	3	2	6
Koru	0	8	10	10	6	10	2	3	5	1	5
Egmont	0	4	8	9	7	6	3	1	3	2	6
Atem	1	12	9	4	4 R	5	7	5	5 R	3 R	5
Golf	0	15	9	9	6	6	4	1	5	2	7
Keg	0	21	23	23	21	20	15	21	16	13	13
Mazurka	2	17	18	16	15	12 R	11 R	9	7 R	11	10
Gunhild	0	17	18	15	11	20	15	14	14	7	9
Zephyr	1	12	8	9	6	13	12	9	7	3	7

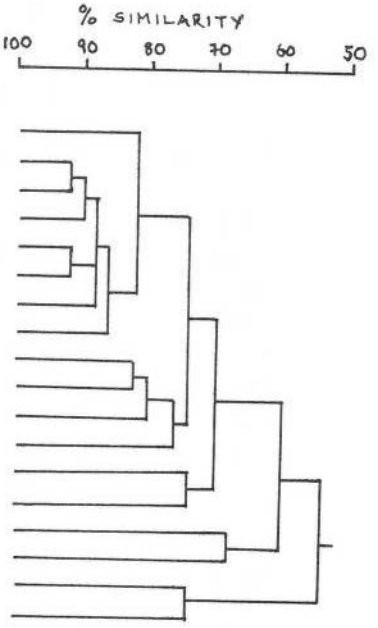
Table 5

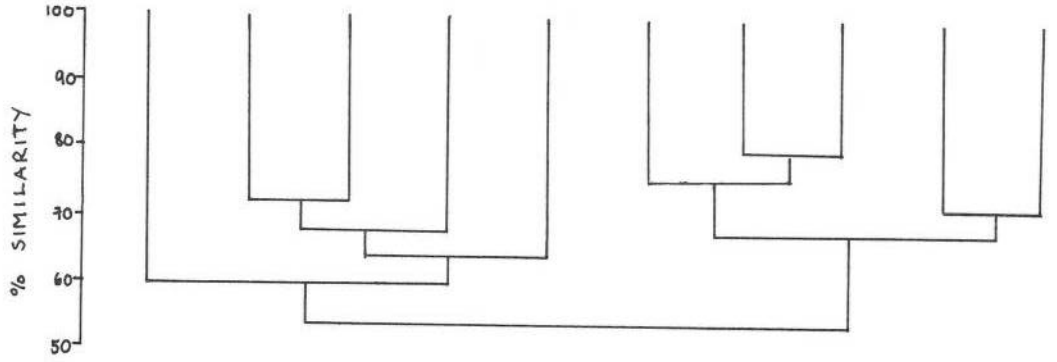
Yellow rust of barley

Multivariate analysis of adult plant test results 1982

Values are 2-factor residuals. Dendrograms are derived by average linkage cluster analysis.

Isolate / Cultivar	80/47	80/129	75/101	80/32	74/33	80/80	81/31	81/49	81/7	81/44
Goldmarker	-2.5	0.3	0.5	-1.0	1.5	0.2	-1.0	0.6	1.1	0.2
Triumph	-1.9	-1.2	-1.5	0.0	0.3	1.3	0.6	0.7	1.5	0.1
Tasman	-1.4	-2.0	-1.7	0.1	-0.8	0.9	1.0	1.4	2.1	0.5
Carnival	-2.2	-2.5	-0.7	-0.1	-0.1	0.0	0.8	1.9	1.3	1.5
Nicole	-1.8	-1.3	0.5	-0.2	-1.2	0.2	0.5	1.4	1.5	0.4
Regent	-0.8	-1.3	0.9	-1.1	-1.1	0.5	0.1	0.4	1.5	0.9
Patty	-1.2	0.3	-2.7	-0.3	-1.4	0.3	0.9	0.9	2.2	1.1
Bigo	-2.3	-1.0	-0.3	1.1	-2.6	-0.3	0.8	0.6	2.3	1.8
Varunda	-0.3	2.4	2.4	-0.6	-0.5	-0.6	-1.8	-1.6	-0.1	0.8
Kym	-0.1	0.1	4.5	0.3	1.8	-0.5	-3.1	-2.5	-1.4	0.8
Koru	0.1	1.4	1.7	0.0	2.3	-3.2	-0.7	0.2	-1.7	0.0
Egmont	-2.7	0.4	1.5	2.6	0.1	-1.5	-2.2	-0.6	-0.2	2.5
Atem	4.3	0.7	-4.3	-1.3	-2.0	1.7	0.9	0.5	-0.1	-0.4
Golf	7.2	0.4	0.0	-0.4	-2.2	-1.2	-3.4	0.0	-1.7	1.4
Keg	0.3	2.2	2.0	2.8	0.1	-2.5	4.0	-1.5	-2.6	-4.9
Mazurka	2.5	3.1	1.0	3.0	-2.3	-1.0	-1.3	-4.0	1.1	-2.1
Gunhild	1.4	1.2	-1.3	-2.5	4.8	1.6	1.8	1.5	-4.2	-4.4
Zephyr	1.4	-3.3	-2.6	-2.3	3.1	4.1	2.2	0.1	-2.6	-0.1





Four 1980 isolates were included in Polythene tunnel tests for a second year to investigate the cultivar x isolate interactions reported in 1981 (Priestley, Bayles and Crofts, 1982). The interactions in question were cultivars Zephyr, Keg and Gunhild with isolate 80/47 and Gunhild and Mazurka with isolate 80/80. There is no evidence that these interactions were repeated in 1982 (Table 6) and it therefore seems unlikely that their appearance in 1981 implied genuine adaptation of the pathogen to particular cultivars. The inconsistency of cultivar x isolate interactions over years indicates that interactions of yellow rust of barley may be more environmentally sensitive than those of yellow rust of wheat, which have usually been reproducible over successive years in Polythene tunnel tests.

Table 6

Comparison of 2-factor residuals for 4 cultivars and 6 isolates in 1981 and 1982

(Residuals derived from total of 36 cultivars x 10 isolates in 1981 and 18 cultivars x 10 isolates in 1982)

	Isolate											
	80/80		80/47		80/29		80/32		75/101		74/33	
Cultivar	'81	'82	'81	'82	'81	'82	'81	'82	'81	'82	'81	'82
Zephyr	-1.6	4.1	18.0	1.4	-1.2	-3.3	1.6	-2.3	-5.5	-2.6	-5.3	3.1
Keg	-1.6	-2.5	22.3	0.3	-5.8	2.2	3.3	2.8	11.3	2.0	-12.3	0.1
Gunhild	16.4	1.6	29.6	1.4	-3.1	1.2	-9.1	-2.5	-8.8	-1.3	-8.4	4.8
Mazurka	15.7	-1.0	4.7	2.5	0.2	3.1	1.2	3.0	-1.0	1.0	-3.6	-2.3

The isolate dendrogram indicates that the isolates fell into two broad groups, one group comprising the 1981 isolates together with 80/80 and the other group comprising the remaining 1980 isolates and the earlier control isolates. However, considering the variable nature of yellow rust of barley test results from year to year, it seems unlikely that this indicates a real change in virulence during recent years.

Almost all the yellow rust of barley samples received in 1982 possessed combined virulence for the two identified overall resistances BYR 1 and BYR 2. Inoculated tests have so far failed to reveal further specific adaptation of the pathogen to current cultivars at seedling or adult plant growth stages and apparent interactions have proved inconsistent from year to year. The emphasis during recent years has been on spring barley cultivars but, with the expansion of the winter barley acreage and the increasing proportion of isolates received from winter barley cultivars, we plan to investigate winter barley cultivar x isolate interactions during 1982/83.

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BROWN RUST OF BARLEY

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

Welsh Plant Breeding Station, Aberystwyth

Isolates of Puccinia hordei Otth. were successfully cultured and tested from all 22 samples of barley brown rust received from the 1982 Survey. Only two virulence patterns were identified - octal designations 673 and 653. The latter occurred in 5 isolates from Lincolnshire, Hertfordshire and Dyfed, which also carried virulence to cvs Triumph and Carnival. Specific resistance was confirmed in a number of winter cultivars tested in isolation nurseries at the WPBS as was virulence to cv. Triumph. The resistance of cv. Vada and its derivatives remains effective and stable (durable).

GLASSHOUSE SEEDLING TESTS WITH 1982 ISOLATES

Only 22 samples of barley brown rust, 15 from winter and 7 from spring cultivars, were received. These were from a wide range of cultivars from Wales, west-central and south-west England. All were successfully cultured and tested on the standard set of differential cultivars, together with cvs Triumph and Carnival, using standard procedures (Jones & Clifford, 1980).

Results

Based on the reactions with the standard differential cultivars, only two patterns of virulence were detected. The first (octal designation 673) is common and widespread, being avirulent only on Pa_7 and Pa_3, and it occurred in 17 of the isolates. The other is similar but lacks virulence on Quinn (Pa_2 + Pa_5) and occurred in 5 isolates. It had not previously been detected and is designated octal 653. Cv. Triumph was resistant to isolate 673, although it is purported to carry resistance factor Pa_9 (Walthur & Lehmann, 1980), which is present in the differential cultivar CI 1243 and which is susceptible to 673. The resistance of cv. Carnival was expressed similarly to cv. Triumph from which it has been bred (see Table 1) which suggests that the resistance is either different from CI 1243 or, if the same, its expression is enhanced in the derived cultivars. The expression of the CI 1243 resistance is variable and is known to be enhanced at lower temperatures in the range 5-25° (Udeogalanya & Clifford, 1978).

Table 1. Differential interactions with representative isolates of Puccinia hordei from the 1982 Survey

Differential	Isolate BRS 82- -9	-15	-18	-22
Sudan - Pa	4	4	4	4
Peruvian - Pa_2	4	4	4	4
Ribari - Pa_3	Oc	Oc	Ocn	Ocn
Gold - Pa_4	4	4	4	4
Quinn - $Pa_2 + Pa_5$	3	4	On,1	On,1,3
Bolivia - $Pa_2 + Pa_6$	3^+	4	4	4
Cebada Capa - Pa_7	On	On	On	On
Egypt 4 - Pa_8	3^+	4	4	4
CI 1243 - Pa_9	3,Oc	4	4	3
Triumph	Oc,3	On,3	4	4
Carnival	3,1,On	3,1,On	4	4
Sultan	3^+	4	4	4
Designation	673	673	653TC	653TC

The five isolates designated 653 which lacked virulence to Pa_5 in Quinn were fully compatible with cvs Triumph and Carnival (see Table 1) and this is of interest because they came from different geographic locations. All 5 were from cv. Triumph, two from isolation nurseries grown at the WPBS, Aberystwyth, two from Rothamsted Experimental Station, Hertfordshire, and one from Croxby, Lincolnshire. These isolates will be further tested in isolation nurseries at the WPBS in 1983 to confirm virulence on cvs. Triumph and Carnival.

ADULT PLANT FIELD TESTS IN ISOLATION NURSERIES

Twenty six cultivars, 12 winter and 14 spring, were grown in each of 3 isolation nurseries in 1981-2 using standard procedures. The nurseries were inoculated with one of the three following isolates of P.hordei:

BIN-1 BRS-81-25 Ex cv. Triumph
BIN-2 Standard Race F (octal 273)
BIN-3 Winter barley isolate

The rate of disease development allowed two assessments to be made on the winter and three on the spring cultivars.

Table 2. Barley brown rust isolation nurseries - WPBS 1982

Cultivar	Isolate BRS-81-25		Race F		ex winter barley	
	%*	RT	%	RT	%	RT
Sonja	1	3	9	4	14	4
Hoppel	2	3,2	6	4,2	11	4
Otter	3	4	6	4	8	4
Athene	2	3	8	4	4	4
Igri	3	3	14	4	12	4
Astrix	1	3	5	4	7	4
Gerbel	5	4	12	4	14	4
Marko	1	3	3	3	8	3
Tipper	1	3	6	4	7	3
Fenella	1	4	5	3	8	4
Pirate	1	3	7	4	8	4
Hydra	2	3	12	4	12	3
Vada	3	3,2	4	4,2,1	1	4,2
Tyra	8	4	8	4	8	3,2,1
Midas	24	4	19	4	21	4
Tintern	3	3,2,1	5	4,2	10	4,2
Armelle	5	4,3	7	3	9	3
Simon	0		0		0	
Triumph	12	4	8	4,2	8	4
Egmont	5	4	6	3,2	11	4,2
Koru	10	4	7	4	13	4
Carnival	4	1,2,3	3	1,2,3	4	On,1,2,3
Kym	6	3,2,1	8	3,2,1	13	4,2
Patty	4	1,2,3	5	1,2,3	7	4,2,1
Goldmarker	18	4	16	4	20	4
Atem	17	4	8	4	14	4

*Mean of 4 replicates at 3 assessment dates (spring cultivars) or 2 assessment dates (winter cultivars)

Results

Reasonable levels of infection developed to allow comparisons to be made between cultivars and between isolates (Table 2). Resistance to isolate BRS-81-25 was expressed by the majority of winter cultivars. Gerbel, Igri, Sonja and Hydra were relatively susceptible to the other 2 isolates whereas Marko, Tipper and Athene were more resistant. In the spring cultivars, Simon (Pa_3) was resistant to all 3 isolates. Cv. Triumph was relatively susceptible, particularly to isolate BRS-81-25 which originated from that cultivar. The response of cv. Carnival is similar to cv. Triumph in the seedling stage (see above) but in these field tests Carnival was relatively resistant suggesting that it may have additional adult plant resistance.

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RHYNCHOSPORIUM OF BARLEY

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

Welsh Plant Breeding Station, Aberystwyth

In seedling tests, a range of known virulence combinations (races) was identified from the 55 samples of Rhynchosporium received from the 1982 survey. A new combination (BRV-3,4) was detected in 4 isolates and carriers are designated race UK-6. Cv. Igri seedling virulence occurred commonly as race UK5 (BRV-1, 2, 3, 4). Isolate : cultivar interactions suggested that cvs Tipper and Gerbel carry the cv. Astrix resistance (BRR-2). Cvs Pipkin and La Mesita (BRR-5) were resistant to all isolates. In field isolation nurseries cvs Armelle and Koru responded similarly suggesting a common resistance (BRR-1). It was confirmed that the resistance in cv. La Mesita (BRR-5) becomes ineffective against race UK5 at the adult plant stage.

SEEDLING TESTS WITH 1982 ISOLATES

A total of 55 samples of barley scald was received, originating as follows:

Geographic origin		Cultivar origin			
		Winter		Spring	
ENGLAND		Igri	25	Triumph	3
East	17	Gerbel	5	Atem	1
South West	12	Sonja	3	Goldmarker	1
West Central	2	Otter	3	Corgi	1
East Central	2	Athene	2	Patty	1
		Tipper	1	Proctor	1
SCOTLAND	14	Breeding line	1	Breeding line	2
		Unknown	4		
WALES	8	Hordeum murinum	1		
Total	55		45		10

Isolates of Rhynchosporium secalis were successfully cultured from 19 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). Isolates were assigned virulence (BRV) factors based on their interactions with the specific resistance factors accorded the differential cultivars.

Resistance factor	Cultivar
BRR-0	Maris Mink
1	Armelle
2	Astrix
3	Athene
4	Igri
5	La Mesita

Results

A range of different known virulence combinations was detected in the 19 isolates of R.secalis successfully cultured, together with a new combination which was detected in four isolates (Table 1).

Table 1. Virulence factor combinations (races) identified from the 1982 survey

Number of isolates	Virulence (BRV) factor(s)	Race
2	0	UK 1
1	1, 2, 3	UK 2
2	3	UK 3
1	1, 3	UK 4
9	1, 2, 3, 4	UK 5
4	3, 4	UK 6

The newly-detected race carrying virulence for BRR-3 in cv. Athene and BRR-4 in cv. Igri is designated race UK6. The most commonly occurring combination was BRV 1, 2, 3, 4 which occurs in Race UK5. In this race the virulence for seedlings of cv. Igri is quite clear-cut although under field conditions isolates carrying BRV-4 fail to cause significant infection on cv. Igri. Three isolates of race UK6 also gave high levels of infection on cv. Hoppel.

Of the other 4 cultivars tested, cvs Gerbel and Tipper gave a similar pattern of response, being resistant to isolates carrying BRV-1, -3 and -4. The other cultivar tested was cv. Pipkin which is known to carry the resistance gene Rh^4 from La Mesita, and it was resistant to all isolates. The isolates which overcame the resistance of cvs Tipper and Gerbel were avirulent on BRR-5 carriers and it is therefore concluded that they carry BRR-2 which is also present in cvs Astrix, Mira and Katy (Jones & Clifford, 1980). These interactions are summarised in Table 2.

Table 2. Interactions between isolates (races) of Rhynchosporium secalis carrying specific virulence factors and cultivars of barley

Pathogen isolate		Cultivar							
Race	Virulence	Armelle	Astrix	Athene	Igri	La Mesita	Gerbel	Tipper	Pipkin
UK 1	0	R	R	R	R	R	R	R	R
2	1,2,3	S	S	S	R	R	S	S	R
3	3	R	R	S	R	R	R	R	R
4	1,3	S	R	S	R	R	R	R	R
5	1,2,3,4	S	S	S	S	R	S	S	R
6	3,4	R	R	S	S	R	R	R	R

ADULT PLANT TESTS WITH 1981 ISOLATES

Two isolation nurseries comprising 16 winter and 11 spring cultivars were sown and assessed in the 1981-82 season using standard procedures. The nurseries were inoculated with one or the other of the following isolates obtained from the 1981 survey.

Survey code	Virulence characteristics
Rs-81-18	Race UK-5 (BRV-1, 2, 3, 4)
Rs-81-77	Race UK-1 (BRV-0)

Results

The results are summarised in Table 3. The isolates differentiated specific resistances in certain cultivars. Cv. Armelle was resistant to UK1 and susceptible to UK5 as was cv. Koru confirming that these cultivars carry the same resistance (BRR-1). A similar response occurred with cv. Fenella although it was relatively resistant to UK5 suggesting that it carries BRR-1 plus additional 'background' resistance. All other winter cultivars, with the exception of Maris Otter, were resistant to both isolates. This includes cv. Igri which is susceptible to UK5 (BRV-1, 2, 3, 4) in the seedling stage (see seedling tests above) and this confirms previous observations (Clifford & Jones, 1982). The seedling tests results suggest that cvs Astrix, Gerbel and Tipper carry the same resistance (BRR-2) and they also showed similar patterns of infection in the isolation nurseries. They were relatively susceptible to race UK5 but would still be classified as 'field resistant' to this isolate, which indicates that they carry adult plant resistance in addition to BRR-2. Conversely, the spring cultivar La Mesita expresses a high level of resistance in the seedling stage to all isolates of R.secalis from the UK surveys but in the field the resistance to race

Table 3. Rhynchosporium isolation nuseries 1982

Cultivar	Rs-81-77 (UK1)				Rs-81-18 (UK5)			
	F-2	F-1	F	$\bar{x}$	F-2	F-1	F	$\bar{x}$
Fenella	0	0	0	0	9	11	0	6.7
Hydra	0.5	0	0	0.2	2	6	4	4.0
Astrix	1	1	2	1.3	2	3	7	4.0
Gerbel	1	1	0.5	0.8	2	5	4	3.7
Tipper	1	1	0.1	0.7	4	9	8	7.0
Hoppel	0.5	0.5	0.2	0.4	2	2	2	2.0
Argus	1	1	0.5	0.8	2	2	4	2.7
Igri	1	1	1	1.0	1	2	6	3.0
Pirate	3	3	1	2.3	2	4	3	3.0
Pipkin	2	3	1	2.0	4	4	1	3.0
Hexa	0.1	1	0.5	0.5	5	5	3	4.3
Marko	3	2	1	2.0	4	5	5	4.7
Sonja	2	2	1	1.67	3	7	6	5.3
Video	0.5	1	1	0.8	4	4	9	5.7
Athene	7	7	3	5.7	9	10	4	7.7
Otter	32	17	6	18.3	35	22	9	22.0
Armelle	0	0	0	0	10	12	10	10.7
Koru	0	0	0	0	21	29	20	23.3
La Mesita	2	5	5	4.0	6	17	20	14.3
Proctor	8	8	4	6.7	10	10	4	8.0
Triumph	18	22	10	16.7	14	18	11	14.3
Atem	19	23	11	14.3	28	25	15	22.7
Patty	17	26	14	19.0	24	33	19	25.3
Goldmarker	19	24	14	19.0	24	32	26	27.3
Kym	11	19	9	13.0	31	38	19	29.3
Egmont	23	21	9	17.7	31	39	26	32.0
Carnival	20	26	16	20.7	31	42	31	34.7

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

UK-5 becomes less effective on the upper leaves (see Table 3) and this confirms a previous observation (Clifford & Jones, 1982). However, in the derived winter cultivar Pipkin, resistance was expressed fully at all stages and it would be interesting to investigate the physiological basis of these differences. The spring cultivars, with the exception of cvs Koru, Armelle and La Mesita noted above, were susceptible to both isolates although cv. Proctor was relatively less infected, confirming its known non specific resistance.

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NET BLOTCH OF BARLEY

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

Welsh Plant Breeding Station, Aberystwyth

Of the 209 samples of net blotch received in 1982, 86 were from winter and spring cultivars sown for the 1981-82 season (summer isolates) and 123 were from crops sown in autumn 1982 (autumn isolates). Isolates of Pyrenophora teres Drechs. were obtained from 83 samples and tested on seedlings of winter and spring cultivars and resistance sources using standard procedures. Frequencies of virulence to cultivars of agricultural importance were high (> 80%) in seedling tests although some such cultivars are resistant in the field. These frequencies were similar in both 'summer' and 'autumn' isolate populations. Virulence to all resistance sources was detected but at very low frequencies for some. e.g. C.I. 5401, C.I. 9820 and C.I. 4502 and these are being used in breeding programmes. The frequencies of some of these virulences differed between summer and autumn populations of the pathogen but the reasons for this are not clear. Isolates carrying between 5 and 9 specific virulences in various combinations were identified.

Two hundred and nine samples of net blotch were received during 1982. Of these, 86 were from winter and spring cultivars sown for the 1981-82 season and the remaining 123 samples were from crops sown in autumn 1982. The majority of samples were from the winter cultivars Igri (66) and Sonja (49) and the greatest number of samples was from eastern England (Table 1). Isolates of Pyrenophora teres Drechs. were made and inoculated onto seedlings of the differential cultivars which included those used in previous surveys with the deletion of cv. Proctor and the addition of C.I. 9214, a recently introduced source of resistance for breeding. Fourteen winter cultivars of agricultural interest were also tested. Test procedures were those reported previously (Clifford & Jones, 1981).

RESULTS

Isolates of Pyrenophora teres from 83 samples of barley net blotch were tested. The remainder failed to culture even with repeated attempts. Fifty eight of these isolates were from winter and spring cultivars grown

Table 1. Origin of samples of barley net blotch for the 1982 virulence survey

Location	No. of samples	Winter cultivar	No. of samples	Spring cultivar	No. of samples
ENGLAND					
East	103	Igri	66	Triumph	6
South West	21	Sonja	49	Ark Royal	3
West Central	19	Gerbel	8	Midas	1
East Central	5	Tipper	6	Atem	1
South	16	Athene	3	Kym	1
North	4	Otter	3	Golden Promise	1
		Hydra	2	Athos	1
WALES	17	Halcyon	1	Corgi	1
		C.I. 9518	1	Brier	1
SCOTLAND	8	Hudson	2	Keg	1
		Volunteers	2	Monto Cristo	1
IRELAND	16	Unknown	20	Volunteers	1
		Breeding line	7	Breeding line	20
Total	209		170		39

during the 1981-82 season (designated 'summer' isolates) and 25 were from crops sown in the autumn of 1982 ('autumn' isolates). Frequencies of virulence to the winter cultivars and the standard differential cultivars are given in Table 2. The data have been arranged to give virulence frequencies in 'autumn' and 'summer' isolates as well as the overall frequencies.

The frequency of virulence to the winter cultivars was generally high being >80% for all cultivars. Some of these cultivars show high levels of resistance in the field, Maris Otter, Pirate and Tipper having NIAB ratings of 8, 8 and 7 respectively (Anon, 1983). It must be concluded therefore that either virulence to these cultivars is becoming more widespread or that field response does not reflect the glasshouse seedling response. To resolve this, it is planned to test selected isolates under field conditions in 1983.

Virulence frequencies for individual winter cultivars were similar in both 'autumn' and 'summer' isolates but this was not the case with regard to the standard differential cultivars. Virulence frequencies were generally much lower on this group (Table 2) and there were some marked

Table 2. Frequencies of virulence to test cultivars of barley in isolates of Pyrenophora teres collected in summer or autumn 1982

Test cultivar	Summer isolates Number tested	Summer isolates Virulence frequency (%)	Autumn isolates Number tested	Autumn isolates Virulence frequency (%)	Overall virulence frequency (%)
Commercial cultivar					
Hoppel	58	98	25	96	98
Athene	58	91	25	72	86
Igri	58	95	25	96	95
Sonja	58	98	24	87	95
Otter	58	97	25	96	96
Gerbel	58	91	25	96	93
Video	48	96	25	100	97
Hexa	58	95	25	92	94
Marko	57	89	25	84	88
Argus	35	86	25	96	90
Fenella	58	83	25	88	84
Pirate	58	82	25	68	76
Tipper	58	86	25	84	85
Pipkin	21	86	25	80	83
Differential cultivar					
C.I. 9518	57	91	25	80	88
Tenn. 61-119	58	53	25	60	55
C.I. 739	56	46	23	26	39
C.I. 4979	56	20	25	48	31
C.I. 1243	58	14	24	54	26
C.I. 4795	47	23	25	20	22
C.I. 6311	51	10	25	40	20
Code 65	56	20	25	8	16
C.I. 9214	48	6	25	16	11
C.I. 4502	21	5	24	8	9
C.I. 5401	51	8	24	4	8
C.I. 9820	55	5	25	8	6

differences between summer and autumn isolates. Virulence to C.I. 6311, C.I. 1243 and C.I. 4979 occurred at a lower frequency in summer isolates whereas the converse appears to be the case for C.I. 739 and Code 65. The most valuable resistance sources, as measured by the low frequencies of corresponding virulence, were C.I. 5401, C.I. 9820, C.I. 4502 and C.I. 9214, all of which are being used in UK breeding programmes.

Table 3. Frequencies of virulences corresponding to each differential cultivar (1979-1982)

Code number	Cultivar	Virulence frequency (%) 1982	1981+	1980*	1979*
1	C.I. 5401	8	0	4	0
2	C.I. 6311	20	0	4	0
3	C.I. 9820	6	0	11	7
4	C.I. 739	39	0	0	7
5	C.I. 1243	27	0	11	20
6	C.I. 4795	22	0	18	0
7	C.I. 4502	9	0	18	7
8	C.I. 4979	31	0	37	20
9	Proctor	-	-	81	87
10	Code 65	16	0	26	33
11	C.I. 9518	88	66	96	93
12	Tenn. 61-119	55	71	55	27
13	C.I. 9214	11	-	-	-

*Clifford and Jones (1981); +Clifford and Jones (1982).

Virulence to all of the differential cultivars had been detected previously but the level of virulence in the population appears to fluctuate considerably between years and even within years. Virulence frequencies over the period 1979-1982 are summarised in Table 3. These virulences occur in various combinations and some isolates were identified which are widely virulent. Virulence combinations based on differential code numbers (Table 3) are given below for selected widely virulent isolates. Each of these also carries virulence for cvs Fenella, Pirate and Tipper.

Isolate	Virulence combination
BNS-82-2	4, 6, 10, 11, 12
BNS-82-5	2, 4, 5, 6, 8, 10, 11, 12
BNS-82-63	1, 2, 4, 5, 7, 8, 11, 12, 13
BNS-82-209	2, 4, 5, 6, 7, 8, 11, 12, 13

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MILDEW OF OATS

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

Welsh Plant Breeding Station, Aberystwyth

In a year of relatively low oat mildew incidence 61 samples were received of which 28 were successfully cultured. Most came from field trials in England and Wales, no samples having been received from Scotland, N.Ireland or Eire. All isolates tested were from spring oat cultivars.

The new cultivar Dula was assigned to OMR group 0 having no known hypersensitive resistance factors.

The virulence combinations OMV 1 + 2 (race 3) and OMV 1 + 2 + 3 (race 5) continued to be the most common, the frequency of the simpler race showing a considerable decrease, while the more complex combination showed an increase compared with the previous year. The latter combination can attack OMR 2 cultivars (Trafalgar, Cabana, Maris Tabard), OMR 3 cultivars (Panema winter oat) and the OMR 1 cultivars Peniarth and Pennal winter oats.

One sample was identified as OMV 1 + 3 (race 4) and four possessed virulence to the Avena barbata (OMR 4) resistance. This virulence was also combined with virulences 1 + 2 + 3 in these four isolates, thus making them capable of attacking all seedling and overall resistance factors available in present day commercial oats.

Direct inoculation from field crops was successfully carried out on detached segments of adult plant leaves using a spore trap, although an improvement in the technique is still desirable. No significant adaptation to the Milo adult plant resistance was apparent, while there was some indication that, on Orlando, specialization in mildew towards its own host had occurred.

SEEDLING TESTS WITH 1982 ISOLATES

From a total of 61 leaf samples received in 1982 only 28 were successfully cultured. Fewer samples were received than in the previous year probably due to the low incidence of oat mildew in several areas during this season. Most samples came from England, 10 from the North, 17 from the East and 12 from the West Central region, while 22 were from Wales. None was received from Scotland nor from Eire or Northern

Ireland. Several co-operators reported that there were generally extremely low levels of oat mildew or even complete absence. None of the samples cultured was from winter oat cultivars and probably this was due to the late development of mildew, by which time the winter oat crop was maturing. The five winter oat samples which were received failed to culture due to senescence of the leaves in transit.

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 (Translocation line of Manod x Avena barbata), the latter having been first used in the 1978 UK Cereal Pathogen Virulence Survey.

Results and Discussion

The resistance grouping of the spring oat cultivar Dula, provisionally recommended by NIAB for 1983, has been determined and the resistance groupings of all recommended spring and winter oat cultivars for 1983 are given in Table 1. The cultivar Dula has been allocated to OMR group 0 (Jones & Jones, 1979), being susceptible to all available mildew isolates carrying the various virulence factors.

Table 1. Resistance grouping of cultivars on 1983 NIAB Recommended List

OMR group	Differential cultivars	Cultivars
0	Milford	Leanda, Dula*, Perona, Saladin
1	Manod	Peniarth(W), Pennal(W)
2	Cc 4146	Trafalgar, Cabana, Maris Tabard
3	9065 Cn 6/3/74	Panema(W)
4	Cc 6490	-

* = New recommendation; (W) = winter oat

Details of the mildew samples tested are given in Table 2, and the frequency of occurrence of the various virulences in 1982 compared with the previous three years is presented in Table 3.

The predominant virulence combinations were again OMV 1 + 2 (Race 3) and OMV 1 + 2 + 3 (Race 5) with 39% and 43% of samples respectively, a

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

Location	Cultivars	Virulences
ENGLAND (North)		
NIAB Trials Cockle Park, Morpeth, Northumberland	Saladin	1 + 2
	Trafalgar	1 + 2 + 3
	Orlando	1 + 2 + 3 + 4
	Orlando	1 + 2 + 3 + (4)*
ENGLAND (West Central)		
NIAB Trials Harper Adams, Newport, Salop	Trafalgar	1 + 2 + 3
	Matra	1 + 2 + 3 + (4)
NIAB Trials Rosemaund, Hereford	Saladin, Trafalgar	1 + 2
	Orlando	
	Perona, Pinto	1 + 2 + 3
WALES		
Ruthin, Clwyd	Trafalgar	1 + 2 + 3
Morfa Mawr (WPBS), Dyfed	Trafalgar, Leanda, Cabana, Perona, Maris Tabard, Saladin, Mostyn	1 + 2
	Milo	1 + 3
	Milo (3 samples), Orlando (2 samples)	1 + 2 + 3
	Orlando	1 + 2 + 3 + (4)
NIAB Trials Trawscoed, Dyfed	Perona, Cabana	1 + 2 + 3

*( ) = in first and subsequent tests of this isolate the reaction on the differential cultivar Cc 6490 (OMR 4) was not completely compatible - slight necrosis present

situation which has prevailed since 1978. However, in the 1982 season the frequency of OMV 1 + 2 (Race 3) showed a decline compared with previous years, while the more complex OMV 1 + 2 + 3 (Race 5) showed an increase compared with 1981 (Table 3). The latter combination is able to attack the cultivars both in OMR group 2 (Trafalgar, Cabana, Maris Tabard) and in OMR group 3 (Panema winter oat) and the OMR 1 cultivars Peniarth and Pennal winter oats. Several new cultivars now in National List trials also possess OMR 3 (9065 Cn) resistance, thus the combined virulence in the more complex race is presumably selected for in preference to the simpler OMV 1 + 2 (Race 3) combination, which is unable to attack successfully cultivars in the OMR 3 group.

Table 3. Virulence group frequencies identified from samples received in 1982 compared with previous three years

Virulence group (race)	No. of isolates in 1982	Frequency (% total) 1982	1981	1980	1979
OMV 1 (2)	0	0	0	0	0
OMV 1 + 2 (3)	11	39	68	51	62
OMV 1 + 3 (4)	1	4	0	3	0
OMV 1 + 2 + 3 (5)	12	43	32	41	38
OMV 1 + 2 + 4 (6)	0	0	0	3	0
OMV 1 + 2 + 3 + 4 (7)	4*	14	0	2	0
Number of isolates tested	28	28	47	63	8

*Three of these isolates, although showing moderate sporulation on Cc 6490, were not completely compatible, slight necrosis being associated with the pustules - see also Table 2 and text

Only one sample from the cultivar Milo (OMR 3) was found to possess the now rare combination OMV 1 + 3 (Race 4), its incidence having been at a low frequency since the decline in cultivation of Mostyn which also possesses OMR 3 resistance. The simple race 2 (OMV 1) was again not detected.

Virulence to Avena barbata resistance (OMR 4), which has not as yet been released in a commercial cultivar, was identified in four samples in 1982. Tests using inoculum from three of these samples did not show complete compatibility on the differential Cc 6490, the reaction being of a type 3, i.e. showing slight necrosis associated with the moderately

sporulating pustules. Each of these isolates also had virulences 1, 2 and 3 combined with 4 (Table 2), thus making the combination capable of attacking all cultivars in commerce. Virulence to OMV 4 (A.barbata) has only been detected previously in the breeding nursery in 1978 and in three samples from the UKCPV Survey in 1980 (Jones & Jones, 1981), none was detected in the intervening years 1979 and 1981.

ADULT PLANT TESTS

The method used to monitor adaptations to adult plant resistances by exposing detached adult leaves of test cultivars directly in mildewed crops (Jones & Jones, 1982) proved unsatisfactory in 1981 as it gave highly inconsistent results.

In 1982, a modification of the method was attempted using a Schwarzbach spore trap (Schwarzbach, 1979) to collect mildew spores from crops and deposit them directly on to detached leaf segments of adult plants of the test cultivars. The following were selected as the test cultivars.

1. Selma - a very susceptible cultivar with no known specific resistance factors;
2. Mostyn - an OMR 3 cultivar which becomes moderately susceptible when infected with corresponding virulence OMV 3;
3. Milo - a new WPBS bred cultivar now in National Trials with the same overall resistance (OMR 3) as Mostyn but with enhanced adult plant resistance compared with Mostyn when inoculated with corresponding OMV 3 mildew.
4. Trafalgar - an OMR 2 overall resistant cultivar which becomes moderately susceptible when attacked by mildew with corresponding virulence (OMV 2);
5. Orlando - also an OMR 2 cultivar which has shown a slightly higher level of adult plant resistance than Trafalgar in trials infected with mildew with corresponding virulence OMV 2;
6. Cc 6490 - a translocation line of Manod (Avena sativa) with A.barbata; possesses the highly effective overall hypersensitive resistance of A.barbata (OMR 4).

Plants of the above six cultivars were grown in spore-free conditions and when the plants were at the post-panicle emergence stage and flowering in the apical spikelets had commenced (GS 61), 2.5 cm long segments were cut from the middle region of the leaf below the flag leaf. As segments

were cut they were placed on water agar (5 g/1) with 150 mg/1 benzimidazole contained in polystyrene boxes (103 x 103 x 20 mm). Each box accommodated 12 segments, i.e. the six cultivars arranged randomly in each of two replicates.

The three cultivars Mostyn, Milo and Orlando were selected to provide inoculum for this experiment which was primarily designed to ascertain whether any Milo and Orlando adult plant adapted strains were present in the mildew populations that developed on these hosts. Pathogenicities were also compared with that from Mostyn. Large isolated plots of these cultivars were being grown for seed multiplication and these conveniently provided sources of inoculum with the minimum of inter-plot contamination. The Mostyn and Orlando plots developed considerable mildew in late June, but Milo remained free of infection until late July when a few restricted areas showed up to 15% mildew. Spore collection was carried out for all three cultivars on 27 July 1982, that for Milo being taken from the most infected areas in the crop.

For collection, a box containing detached leaf segments was fitted to the base of the spore trap and the latter held in the leaf canopy slightly below the level of the uppermost leaves; spore collection proceeded for 2 min. for each sampling. The inoculated boxes were incubated on a laboratory bench receiving ample natural daylight of about 15 h duration and temperature ranging from 15-25°C. After 7 days the percentage leaf segment area showing mildew pustules was assessed using the scale of Jones & Hayes (1971).

Results and Discussion

No mildew symptoms developed on segments of the translocation line Cc 6490 after inoculation with either of the three inoculum sources, consequently this tester line was omitted from any further analyses. Virulence to the A.barbata resistance (OMR 4), as tested with adult plant leaves, appears to be absent from these particular spore collections.

The other test cultivars showed fairly consistent levels of infection and the percentage leaf segment area covered with mildew was recorded for each segment. The mean values are presented in Table 4.

Table 4. Percentage leaf segment area infected with mildew

Cultivar of inoculum origin	Test cultivars: Selma (OMR 0)	Mostyn (OMR 3)	Milo (OMR 3)	Trafalgar (OMR 2)	Orlando (OMR 2)
Mostyn (OMR 3)	25.0	9.50	7.75	4.25	3.75
Milo (OMR 3)	18.0	8.25	6.75	0.50	0.00
Orlando (OMR 2)	10.5	0.00	0.00	7.50	20.25

The inoculum produced on Milo was avirulent on the adult leaf segments of the OMR group 2 cultivars Trafalgar and Orlando, while the inoculum from Orlando (OMR 2) was avirulent on the OMR cultivars Mostyn and Milo. It appears, therefore, that the complex and prevalent race 5 (OMV 1 + 2 + 3) with combined virulences to both OMR 2 and OMR 3 cultivars was not present in the Milo and Orlando sources or at least they were not detected in these adult plant tests. In future it is intended to include segments of seedling leaves in the tests for comparison.

In order to make the results from the three inoculations more comparable a procedure, used by Wolfe & Wright (1976) and Bennett (1981) to compare relative pustule numbers in barley and wheat mildew tests, was applied to these data. Each value (percent segment area infected) was expressed as a percentage of the susceptible Selma, the value for this cultivar thus becoming 100 for each inoculation (Table 5).

Table 5. Standardized infection levels on adult plant segments of five test cultivars inoculated with spores from three field crops

Source of inoculum	Test cultivars: Selma (OMR 0)	Mostyn (OMR 3)	Milo (OMR 3)	Trafalgar (OMR 2)	Orlando (OMR 2)
Mostyn (OMR 3)	100	38	31	17	15
Milo (OMR 3)	100	46	38	3	0
Orlando (OMR 2)	100	0	0	71	193

From Tables 4 and 5 it is apparent that inoculum from Mostyn and Milo was not particularly adapted to its respective host cultivar, but mildew from Orlando proved very infective on Orlando itself compared with Trafalgar in the same OMR group. The enhanced level of adult plant resistance in Milo was probably the reason for the lower value than for Mostyn when inoculated both with mildew from Milo itself (38%) and also from Mostyn

(31%). However, there is some indication of adaptation in Milo in that it has a slightly higher relative value (7 units) when inoculated with mildew from the Milo as compared with that from the Mostyn plot.

In order to test whether these are significant and not error differences, an analysis of variance of the original recordings was carried out. As the values were percentage areas covered with mildew, a logit transformation was employed and, because of zero values, 1.0 was added to each before transformation. As expected, there were significant differences ($P \leq 0.05$) between test cultivars, but no overall difference between the three inoculum sources. The interaction of inoculum sources with test cultivars was significant at $P \leq 0.01$, which resulted from the specificity of the two OMR groups involved in the experiments. Mean values are presented in Table 6. The differences between Milo when

Table 6. Mean percentage leaf segment area infected + 1 (logit transformed)

Inoculum source	Test cultivars					Mean (LSD=±0.3810)
	Selma	Mostyn	Milo	Trafalgar	Orlando	
Mostyn	-0.5585	-1.2865	-1.1890	-1.4755	-1.6565	-1.2332
Milo	-0.7935	-1.2005	-1.2515	-2.1220	-2.2980	-1.5331
Orlando	-1.0375	-2.2980	-2.2980	-1.2340	-0.8105	-1.5356
Mean (LSD=±0.4919)	-0.7965	-1.5950	-1.5795	-1.6105	-1.5883	

LSD to compare inoculum source/test cultivar means = ±0.8520

infected with Milo versus Mostyn inoculum proved non-significant and Milo was not significantly more resistant than Mostyn to the above two inoculum sources. However, the error variance in these tests is considered to be still much too high (C.V. = 28%) and several improvements to the method will be included in the forthcoming season in an attempt to reduce it. These include (a) more replication of leaf segments per cultivar, which can be attained through a reduction in the number of test cultivars used in any one sampling, (b) more precisely controlled environment for incubation and (c) examine the possibility of segments from two or three leaves below the flag leaf giving more consistent results than the flag-1 leaf.

Several advantages accrue from using leaves from adult plants to directly assess the pathogenicity or aggressiveness of the mildew population generated by crops of adult plant resistant cultivars. Results are readily available which avoid the necessity for repeated culturing of sampled inoculum over winter for testing on adult plants in isolation nurseries during the following summer. Furthermore, it excludes any likelihood of adaptation occurring during multiplication of cultures, a possibility pointed out by Clifford & Clothier (1974).

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CROWN RUST OF OATS

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

Welsh Plant Breeding Station, Aberystwyth

Only four samples of oat crown rust were received from late-infected tillers of cvs Perona, Trafalgar and Cabana and from spring-sown cv. Rosette grown at Nickerson's RPB Ltd, Lincolnshire. Only one virulence combination (race) was identified. This is similar to race 372 on the international register which is virulent on cvs Appler, Bond, Landhafer (resistance present in cv. Trafalgar) Ukraine and Saia and avirulent on cvs Anthony, Victoria, Santa Fe, Trispernia and Bondvic. This isolate differs from race 372 in being avirulent on cv. Ukraine and represents a hitherto undetected virulence combination.

VARIETY DIVERSIFICATION SCHEMES FOR WINTER WHEAT AND SPRING BARLEY, 1983

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 1983 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 1983

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

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

DG 1A
Stetson

DG 1B
Avalon
Bounty
Fenman
Galahad
Longbow

DG 1E
Aquila
Flanders

DG 2B
Hustler
Mardler
Maris Huntsman
Virtue

DG 3B
Norman

DG 4C
Armada

DG 6B
Brigand

DG 6F
Rapier

DG 7D
Stuart

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 1A	DG 1B	DG 1E	DG 2B	DG 3B	DG 4C	DG 6B	DG 6F	DG 7D
DG 1A	+	+	+	+	+	+	+	+	+
DG 1B	+	m	+	m	m	+	m	m	+
DG 1E	+	+	m	+	+	+	+	m	+
DG 2B	+	m	+	ym	m	+	m	m	+
DG 3B	+	m	+	m	ym	+	m	m	+
DG 4C	+	+	+	+	+	ym	+	m	+
DG 6B	+	m	+	m	m	+	ym	ym	+
DG 6F	+	m	m	m	m	m	ym	ym	m
DG 7D	+	+	+	+	+	+	+	m	ym

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

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN SPRING BARLEY 1983

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

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

DG 0
Golden Promise

DG 1
Atem

DG 2
Carnival
Midas

DG 3
Cerise
Flare
Georgie
Golf
Koru
Kym
Sundance
Varunda

DG 4
Goldmarker
Goldspear

DG 5
Athos
Patty
Piccolo
Regent

DG 6
Ark Royal
Keg
Tasman
Triumph

DG 7
Gunhild
Tyra

DG 10
Egmont

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