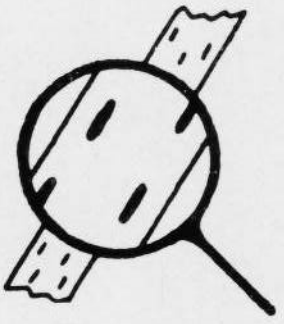
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1980 Annual Report

UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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1980 Annual Report

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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 numbered 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

CONTENTS

THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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

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 varieties and breeding programmes.

Secondary objectives include providing information for varietal diversification schemes, monitoring the frequency of virulences and virulence combinations, evaluating the compatibility of virulences with one another and measuring the effect of changes in variety on the pathogen population.

OPERATION

The Survey is carried out on an annual basis. In April, a list of cereal varieties from which disease samples are requested is sent to about 100 pathologists and agronomists within the United Kingdom. They 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 of barley.

At these centres, virulence tests are carried out using spores multiplied from the disease samples. In the mildews, virulence is measured by inoculating detached seedling leaf segments. In the rusts, both seedling leaves (attached) and adult plants are usually inoculated as previous work has shown that a number of the resistances involved are ineffective at the seedling stage. Seedling tests are usually carried out under controlled environment conditions. Adult plant tests are carried out in the field 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 year. The results are used to place winter wheat and spring barley varieties 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 a number of 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 one or both varietal 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'.

CURRENT RESEARCH

In order to realise its objectives the Survey is actively engaged in research projects through those Committee members working at the three testing centres. The projects are aimed at improving our knowledge of the interaction between host and pathogen populations and at present include the use of mobile nurseries, the improved detection of adult plant virulence, the development of movable Polythene tunnels, the effect of variety mixtures on the pathogen population, the recognition of durable forms of resistance and the development of improved numerical techniques for analysing host-pathogen data matrices.

MILDEW OF WHEAT

Fiona G.A. Bennett and Thea Van Kints
Plant Breeding Institute, Cambridge

Samples analysed in 1980 fell into three groups: those received in the usual way from CPVS contributors, those collected in a new type of spore trap and those taken from plots in cultivar mixture trials.

Direct comparison of pathogenicity was made between the first two sets of samples. Results were similar for most wheat mildew virulence (WMV) types and selection against non-matching types was thought to account for discrepancies. Unbiased spore trap sampling allowed relative pathogenicity levels of the four WMV groups matching resistances used in commercial cultivars to be compared around the UK.

Since no cultivars with new wheat mildew resistance (WMR) combinations or types were recommended, more detailed analysis of the four WMV groups matching resistances in current cultivars was carried out. This applied to samples from four such cultivars and from one cultivar possessing no identified resistance, to spore trap samples and to samples taken from mixture trials. It enabled an assessment of the value of diversification and mixing between cultivars in currently used WMR groups to be made.

INTRODUCTION

Previous wheat mildew surveys have shown that wheat mildew virulence (WMV) types matching wheat mildew resistance (WMR) types present in cultivars grown in UK are either common in mildew populations or readily selected in the presence of appropriate cultivars. Analysis of 1980 samples was therefore aimed at a secondary objective of the CPVS, that is to provide information for cultivar diversification schemes. In addition, the effect of cultivar mixtures on mildew populations was investigated. In both cases, use was made of a sequential testing scheme which allowed actual pathogenicity of certain WMV combinations to be compared with that expected from total levels observed in the traditional way.

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 mean pathogenicity have been discussed in greater depth elsewhere (Bennett, 1980).

A new method of sample collection, using a car-mounted spore trap, was compared with the conventional leaf sampling method.

METHODS OF SAMPLE TESTING

Samples received

Samples were particularly requested from crops and plots of five commercial cultivars, Hobbit, Bounty, Aramada, Flanders and Maris Huntsman. These cultivars respectively represent five wheat mildew resistance (WMR) groups, 0, 2, 4, 8 and 2+6 (see Table 2). All winter wheat cultivars recommended by NIAB in 1980 belonged to one or other of these groups. To preserve the integrity of these samples until testing, they were maintained on seedlings of their source cultivars. Samples were also requested from 20 additional winter and five spring cultivars. These were maintained on Hobbit. Details of samples received, their subsequent fate and the WMR groups to which source cultivars belonged are given in Table 1. The WMR group now called 'Sona 227' represents a distinct but incomplete seedling resistance derived from the Mexican cultivar Sona 227.

Random samples of pathogen populations were collected during July using a new type of wind impaction spore trap (WIST; see Wolfe, Slater & Minchin, this report) mounted on top of a car. By exposing seedlings of Hobbit in the WIST, and changing these at intervals, samples from specified areas of the country were obtained. Infected leaves of exposed seedlings were subsequently detached and the bulk isolates maintained in the usual way.

To obtain more information about the effect of cultivar mixtures on pathogen population structure, leaf samples were collected from plots of two wheat mixture trials in the Cambridge area. In addition, mobile seedling nurseries were placed at regular intervals in certain plots of one of these trials (at the Plant Breeding Institute). After seedling infection had been scored, samples were kept from cv. Minister (WMR 0) and subsequently analysed as described below.

Differential tests

Bulk isolates from samples sent in and from WIST samples were inoculated onto detached seedling leaves of 14 differential cultivars, listed in Table 2.

Table 1. Details of samples received in 1980

WMR Group	Source cultivar	Number of samples Received	Failed to establish	Died in culture
0	Abele	8	0	4
	Copain	1	1	0
	Hobbit	14	2	3
	Kador	12	1	3
	Minister	6	2	1
	Prince	5	0	2
	Ranger	6	1	1
	Rapier	8	1	3
2	Avalon	6	2	3
	Bilbo	5	1	2
	Bounty	24	4	9
	Galahad	4	0	1
	Mithras	7	1	2
	Norman	8	1	3
	Sentry	8	1	1
	Sportsman	3	1	0
	Wizard	4	1	0
4	Armada	17	1	7
7	Baron	5	3	0
	Clement	2	0	1
	Stuart	5	1	2
8	Aquila	10	2	1
	Flanders	24	2	12
	Waggoner	1	0	1
2+6	Brigand	8	2	1
	Fundin	3	1	0
	Huntsman	15	2	2
	Hustler	5	1	1
	Kinsman	8	4	1
	Mardler	11	2	3
	Templar	3	0	2
	Virtue	7	2	2
2+4+6	Timmo	4	0	0
5+8+?	Sicco	2	0	0
(Sona 227)	Highbury	3	2	0
	Sandown	1	1	0
?	Amigo	1	0	0
	Broom	2	1	0
	PBI glasshouse	1	0	0
	Total	267	47	74

Table 2. WMR group definitions: differential cultivars and indentified resistance genes where known

WMR group	Gene	Differential cultivar
0	-	Hobbit
2	Pm2	Bounty
4	Pm4b	Weihenstephan M1
5	Pm5	Hope
6	Pm6	Timgalen
7	Pm8	Stuart
8	? *	Flanders
9	Pm2 + 'M1d'	Maris Dove
2+4		Sappo
2+6		Brigand [1], Maris Huntsman [2]
5+8+?		Sicco
2+4+6		Timmo
2+6+8		Crossbow

*Presently known as 'Ibis'

Differentials were similar to those used in 1979 (Bennett, 1980) except for the substitution of Stuart for Salzmünde 14/44 as the WMR 7 differential, the addition of Crossbow as the WMR 2+6+8 differential, and the deletion of Anfield since WMR 1 is no longer represented by any cultivar in commerce. The identified resistance genes upon which WMR groups are based are given in Table 2. Colony numbers were counted automatically and mean pathogenicity values were calculated as described above and previously (Bennett, 1980).

Sequential tests

In addition to conventional differential tests, certain isolates were subjected to a sequential form of analysis similar to that suggested by Wolfe & Schwarzbach (1975). The purpose of this analysis was to ascertain the frequencies of combinations of pathogenicity characters matching resistances common in agriculture. Table 3 summarises the testing scheme. This method was used to analyse samples from Hobbit, Bounty, Armada, Flanders and Maris Huntsman, WIST samples, and mixture trial samples.

Table 3. Sequential testing scheme to obtain estimates of the relative mean pathogenicity values of all possible combinations of the pathogenicity characters corresponding with WMR groups 2, 4, 8 and 2+6. After Wolfe & Schwarzbach (1975)

	Test cultivars (WMR group in parentheses)										
	Bounty (2)			Armada (4)			Flanders (8)		Maris Huntsman (2&6)	Hobbit (0)	
Primary test: mean pathogenicity value		a* ↓			b ↓			c ↓		d	100
	(2)	(4)	(8)	(4)	(8)	(2+6)	(8)	(2+6)			
Secondary test: mean pathogenicity value	100	e	f	100	g ↓	h	100	i			
				(8)	(2)	(2+6)					
Tertiary test: mean pathogenicity value				100	j	k					

Analysis

Total frequencies from primary test				Mean pathogenicity values of WMV combinations										
											8 + 2+6	4 + 2+6	2 + 4+8	4+8 + 2+6
2	4	8	2+6	2	4	8	2+6	2+4	2+8	4+8				
a	b	c	d											
Expected (calculated from total frequencies)				a-d-ab -ac+bd+ cd+abc	b-ab -bc+ abc	c-ac -bc+ abc	d-cd -bd+ bcd	ab-bd -abc+ bcd	ac-cd -abc+ bcd	bc- abc	cd- bcd	bd- bcd	abc- bcd	bcd
Observed (calculated from primary, secondary and tertiary tests)				a-d-ae -af+bh+ ci+bgj	b-ae -bg+ bgj	c-af -bg+ bgj	d-ci -bh+ bgk	ae-bh -bgj+ bgk	af-ci -bgj+ bgk	bg- bgj	ci- bgk	bh- bgk	bgj- bgk	bgk

*lower case letters a-k represent hypothetical results

Table 4. Mean pathogenicity of 114 bulk isolates received in 1980

WMR group	Source cultivar	Wheat mildew virulence (WMV) group as represented by differential cultivars* 2	4	5	6	7	8	9	2+4	2+6[1]	2+6[2]	5+8+?	2+4+6	2+6+8	Number of isolates
0	Abele	93†	45	59	24	39	64	42	23	56	37	27	8	37	5
	Hobbit	84	12	61	42	<1	69	20	11	57	46	35	9	23	10
	Kador	56	9	60	35	0	59	3	2	46	33	22	3	11	8
	Minister	67	13	46	40	0	42	12	39	56	44	0	4	10	2
	Prince	42	41	83	13	0	76	2	6	4	3	66	<1	3	3
	Rapier	78	41	40	42	5	47	32	26	33	24	26	8	5	4
2	Bilbo	74	9	63	77	0	97	0	0	108	71	33	0	35	2
	Bounty	94	18	56	39	1	63	6	1	63	37	34	0	30	6
	Galahad	92	0	66	61	51	73	12	1	65	75	4	0	53	2
	Mithras	67	0	43	35	12	35	16	0	89	71	14	0	17	3
	Norman	103	16	47	36	0	56	1	13	62	35	30	19	40	2
	Sentry	101	70	76	26	4	81	55	52	27	17	57	2	14	4
	Sportsman	77	3	35	78	0	30	6	1	77	54	19	2	39	2
	Wizard	112	4	60	21	0	53	0	0	94	41	85	0	46	1
4	Armada	69	97	56	28	0	55	39	55	29	24	46	26	18	10
7	Baron	90	3	100	27	96	58	0	0	79	51	25	0	18	2
	Clement	89	0	94	41	77	27	37	0	83	65	0	0	67	1
	Stuart	78	0	4	39	70	12	2	0	87	71	0	0	0	2
8	Aquila	72	19	62	32	<1	82	34	19	20	20	49	<1	21	7
	Flanders	67	30	62	16	<1	54	29	24	27	16	31	<1	18	8

Table 4 (contd.)

2+6	Brigand	94	35	2	53	1	3	26	9	83	60	<1	21	21	3
	Hustler	72	64	45	37	<1	43	33	35	92	67	24	45	30	3
	Kinsman	107	63	23	63	0	40	67	0	114	73	5	0	17	2
	Mardler	101	27	66	59	0	80	24	2	105	75	43	7	48	4
	M. Fundin	88	0	1	71	0	2	0	4	97	88	0	0	0	1
	M. Huntsman	76	15	43	66	<1	46	8	3	90	75	14	9	27	9
	Virtue	73	2	57	56	0	67	10	0	111	77	32	0	51	3
5+8+?	Sicco	43	0	52	69	0	75	88	0	91	69	73	0	75	1
2+4+6	Timmo	88	98	51	84	0	65	47	45	117	75	58	79	51	3
Unknown	Broom	0	0	74	0	0	86	0	0	0	0	96	0	9	1

*Differential cultivars as given in Table 2

†Mean of all isolates from a given source cultivar, excluding those non-pathogenic on matching differential.

Mobile nursery tests

Healthy seedlings of Hobbit, Bounty, Armada, Flanders and Maris Huntsman were exposed on 29 occasions at different locations in the Cambridge area, in both commercial crops representing the five WMR groups referred to above and trials where matching virulence was thought to occur. The intention was to assess the probable value of diversifying and mixing amongst cultivars in these WMR groups.

RESULTS AND DISCUSSION

Differential tests

1. CPVS Samples

Table 4 shows the results of analysis for 114 samples sent in on the complete set of differential cultivars (Table 2). Results from specific isolates are available on request. The pattern of results obtained coincided with expectation from previous survey work, with mean pathogenicity value generally being high for the WMV group matching the WMR group of the source cultivar. The WMR 2+6+8 differential results showed that the matching WMV combination is frequent, occurring with fairly high mean pathogenicity in the majority of samples. This suggests that cultivars in this WMR group may not maintain their resistance if grown on any scale. Also noticeable is the continuing increase in pathogenicity value of WMV 2+6 even in samples from non-matching cultivars. This is also shown in Table 6 (see below). Although cv. Abele is classified in WMR 0, three out of the five samples from it contained high frequencies of WMV 7. Abele is a sister line of Baron (WMR 7) but unlike Baron has no identifiable resistance at the seedling stage. It is possible, however, that the WMR 7 resistance only functions in adult plants of Abele, accounting for the high frequency of WMV 7 in some samples from field crops of this cultivar. This remains to be tested.

2. WIST Samples

These were divided into four groups and the collecting areas covered by each are shown in Figure 1. Table 5 gives the mean pathogenicity values of bulked samples on the complete set of differential cultivars (Table 2). Since these samples are composed of random collections from the air spora, the results should be unbiased but may be influenced by cultivar popularity in a given area. It is hoped that detailed comparisons between separate WIST

Figure 1. Map to show routes taken (1-4) while collecting WIST samples; total frequencies of WMV 2, 4, 8 and 2+6 are shown as histograms

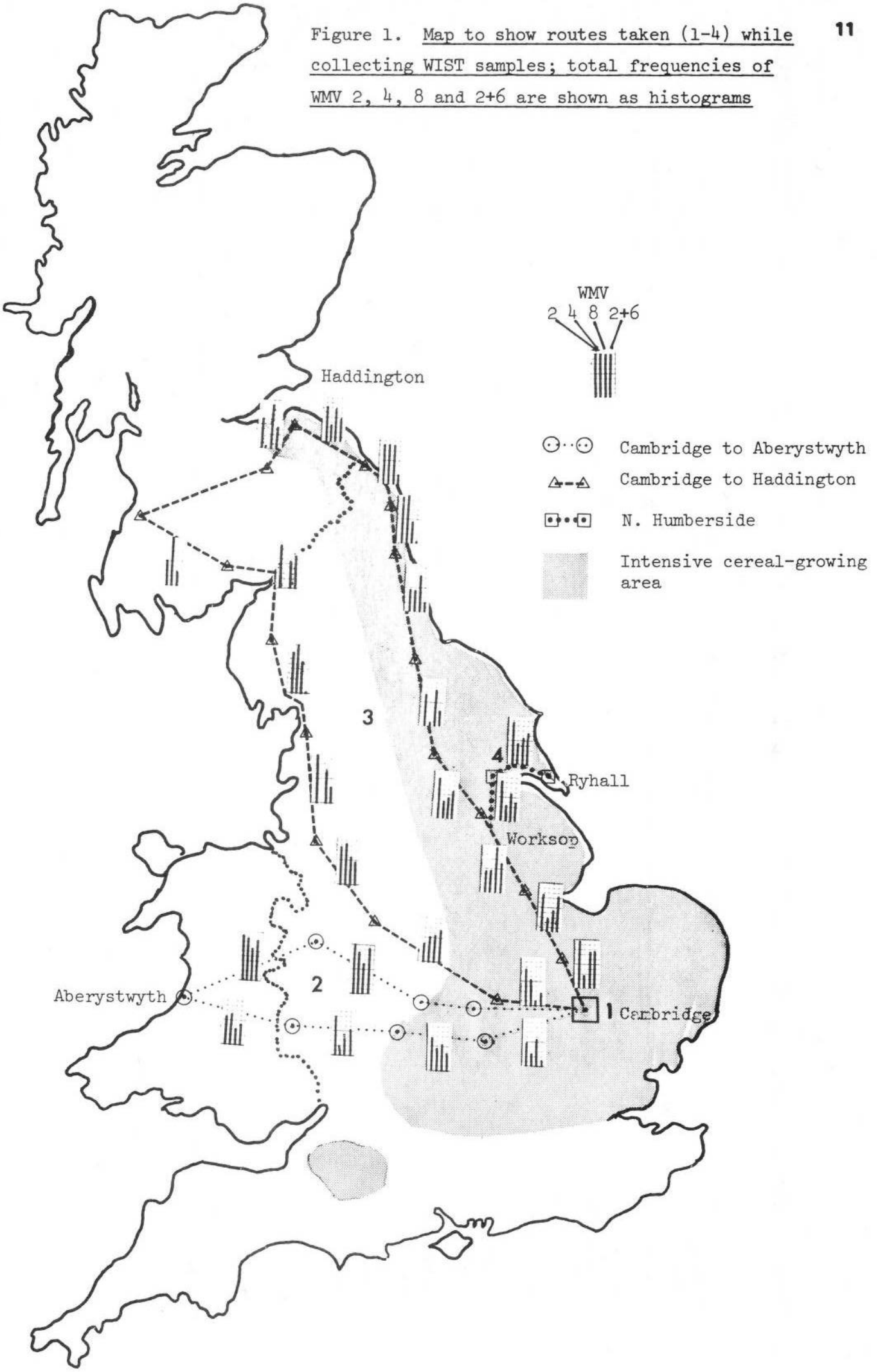

Table 5. Mean pathogenicity values in WIST samples collected July 1980 (see Fig. 1 for route) on full differential test set

Journey between	Map Ref. No.	WMV group as represented by differential cultivars* 2	4	5	6	7	8	9	2+4	2+6[1]	2+6[2]	5+8+?	2+4+6	2+6+8	Number of isolates
Local journeys using prototype	1	70	39	78	24	1	70	9	13	48	34	28	7	23	12
Cambridge to Aberystwyth	2	63	59	53	35	7	81	15	18	49	55	44	26	46	5
Aberystwyth to Cambridge	2	50	35	33	27	6	47	26	26	31	25	16	9	11	8
Cambridge to Haddington	3	72	60	50	22	1	58	29	30	38	28	24	8	18	15
Haddington to Cambridge	3	71	50	66	29	10	70	39	25	58	42	32	11	19	19
Worksop Ryhall	4	83	50	67	51	2	63	21	16	82	67	30	17	30	4
Ryhall to Worksop	4	89	33	37	26	6	59	7	18	53	52	10	36	2	3

*Differential cultivars as given in Table 2

samples and cultivar distribution will be made. All WMV types are represented in all sample groups with relatively high pathogenicity values except WMV 7. In several cases, values are higher in groups from the eastern part of the country (1, 3 return, 4), coinciding with the most intensive cereal growing areas. Nevertheless, results of groups from western areas (2, 3 outward) demonstrate the efficient and extensive spore dispersal of all WMV types. Comparison of mean pathogenicity levels obtained from CPVS and WIST samples is made in Table 6, where results from previous surveys are also shown. For 1980, the correlation between results from conventional samples and the mean of all WIST samples is generally good. When WIST samples obtained from the intensive cereal-growing, eastern part of the country are compared with 1980 CPVS samples, considerably higher pathogenicity values for certain WMV types are observed. These include WMV 4, 8, 2+6 and 2+4+6. This deviation may indicate that these types are selected against in established infections on non-matching hosts but continue to be released in large quantities from matching hosts into the air. Table 6 also shows a sudden increase in 1980 of WMV 2, 4 and 8 pathogenicity in CPVS samples, which can again be related to cultivar popularity.

Sequential tests

1. CPVS samples received from and maintained on Hobbit, Bounty, Armada, Flanders and Maris Huntsman.

The testing scheme shown in Table 3 enabled results from these samples to be broken down into component WMV types and combinations and comparison to be made between observed and expected pathogenicity values (Table 7). Simple WMV types were generally rare in all samples, with double and triple combinations being more common. This result was to be expected since the relatively high frequencies of these WMV types in the general population (Tables 5 & 6) would, by simple probability, lead to their being combined together in pathogen individuals. Only samples from Armada and Maris Huntsman showed relatively high values for matching single WMV types (4 and 2+6 respectively). Despite the apparent abundance of combined pathogenicity characters, it is notable that non-matching WMV types were rarely found except for a high value for WMV 2 in samples from Flanders. Although the most complex combination, WMV 4+8+2+6, was present in all samples except those from Flanders, and had an unexpectedly high value in samples from Armada, the selection against completely non-matching types on all cultivars indicates that cultivar diversification and mixing

Table 6. Mean pathogenicity levels from population surveys 1976-1980 (excluding values for samples from cultivars with matching resistance) compared with those from WIST samples collected in 1980

Type of sample	Year	WMV group as represented by differential cultivars*													Number of Samples
		2	4	5	6	7	8	9	2+4	2+6[1]	2+6[2]	5+8+?	2+4+6	2+6+8	
CPVS	1976	66	6	23	-	1	41	29	5	-	2	-	-	-	78
	1977	80	17	41	-	1	48	44	18	-	2	29	8	-	52
	1978	53	6	23	13	5	31	23	6	-	14	14	2	-	67
	1979	47	4	42	28	0	39	15	6	-	30	18	2	-	59
	1980	72	22	54	35	4	56	23	16	48	35	31	7	25	114
WIST (East)	1980	73	45	68	30	6	68	25	20	57	43	29	12	20	38
(West)		64	53	46	26	4	59	26	27	38	32	25	12	21	28
Mean E & W		69	49	58	28	5	64	26	24	48	38	28	12	21	66

* See Table 2

Table 7. Observed (o) and expected (e) values of mean pathogenicity of combinations of WMV 2, 4, 8 and 2+6 in samples received from and maintained on Hobbit, Bounty, Armada, Flanders and Maris Huntsman

Source cultivar	WMR group	Total frequencies from primary test					Mean pathogenicity values of WMV combinations											Number of samples
		2	4	8	2+6		2	4	8	2+6	2+4	2+8	4+8	8 + 2+6	4 + 2+6	2 + 4+8	4+8 + 2+6	
Hobbit	0	55	4	49	29	o	0	1	2	12	0	28	0	15	0	1	3	11
						e	13	1	21	15	1	13	1	13	0	0	1	
Bounty	2	100	51	72	62	o	0	0	0	16	19	3	0	38	1	24	7	14
						e	14	0	0	8	5	13	0	22	9	14	23	
Armada	4	76	98	55	55	o	0	21	0	0	9	0	0	0	12	12	44	14
						e	1	11	0	1	9	1	13	0	24	11	30	
Flanders	8	73	14	76	49	o	20	0	0	0	0	14	0	64	0	18	0	19
						e	16	1	22	10	0	15	3	32	2	3	5	
Maris Huntsman	2+6	91	23	43	89	o	2	0	0	38	0	0	0	25	3	0	23	10
						e	40	1	3	40	1	1	1	29	11	0	9	
Overall mean		79	38	59	57	o	6	4	0	13	6	9	0	28	3	11	15	
						e	20	3	9	15	3	9	4	19	9	6	14	

would still be advantageous. There were several striking discrepancies between observed and expected values, especially for simple WMV types, reflecting selective disadvantage where observed was lower than expected (2, 8, 2+4+6), or selective advantage where observed was higher than expected (2+6+8). This knowledge would be of obvious value in the choice of cultivars for diversification and mixing schemes, although diversity of background resistance genes might still reduce the spread of mildew between cultivars even where appropriate WMV combinations were present or at a selective advantage.

Mobile nursery results (Table 8) suggest that WMR 2 cultivars would be of little value in diversification since WMV 2 was common to all the host groups examined. Similarly, WMV 8 occurred frequently whereas WMV 4 and 2+6 were only strongly selected on matching hosts. These results generally support the data shown in Table 7. However, there is no means here of examining pathogenicity levels of WMV combinations (other than by calculating expected values). It should also be noted that mobile nurseries measure the 'escaping' population rather than the 'resident' one and it has already been shown that these may differ (Table 6).

Table 8. Colony numbers occurring on seedlings of Bounty, Armada, Falnders and Maris Huntsman when placed in crops of cultivars representing WMR groups 0, 2, 4, 8 and 2+6, expressed as percentage of colony number occurring on seedlings of Hobbit

WMR group of source cultivars	Number of exposures	2	4	8	2+6
0	5	113	13	115	42
2	5	83	10	74	27
4	3	66	80	81	36
8	6	85	19	120	38
2+6	6	86	9	82	62

2. WIST samples

The data shown in Table 9 was obtained by analysis of the same samples as those used for Table 5. The basic pattern of results in Table 9 is similar to that in Table 7. When the overall mean values in these two tables is compared, values in the WIST samples (Table 9) are generally higher

Table 9. Observed (o) and expected (e) values of mean pathogenicity of combinations of WMV 2, 4, 8 and 2+6 in WIST samples collected on three trips in July 1980 (see Fig. 1 for route)

	Journey between	Total frequencies from primary test					Mean pathogenicity values of WMV combinations										Number of colonies contributing
		2	4	8	2+6		2	4	8	2+6	2+4	2+8	4+8	8 + 2+6	4 + 2+6	2 + 4+8	4+8 + 2+6	
2	Cambridge - Aberystwyth (Northern)	65	94	69	57	o	77	39	14	19	0	0	43	13	13	31	12	206
						e	37	10	1	1	2	1	23	2	17	5	37	
	Aberystwyth - Cambridge (Southern)	84	45	45	42	o	0	0	0	24	34	36	7	5	3	1	10	815
						e	21	4	4	13	11	11	3	10	10	8	9	
3	Cambridge - Haddington (Western)	75	44	46	47	o	0	5	4	25	15	16	9	11	9	4	2	397
						e	18	6	6	14	7	8	5	12	11	5	10	
	Haddington - Cambridge (Eastern)	75	43	64	48	o	0	0	7	13	20	10	4	27	4	12	14	848
						e	20	4	9	9	3	9	7	18	8	8	13	
4	Worksop - Ryhall	71	25	39	51	o	0	0	0	43	12	44	15	7	1	10	0	91
						e	14	4	8	23	3	6	3	15	8	2	5	
	Ryhall - Worksop	100	35	57	37	o	0	0	0	14	9	81	5	5	14	4	4	294
						e	25	0	0	10	9	23	0	14	6	13	7	
	Overall mean	78	48	53	47	o	13	7	4	23	15	31	14	13	7	10	7	
						e	23	5	5	12	6	10	7	12	10	7	14	

than those in the conventional samples (Table 7). This effect was also noted in Table 6 and again indicates that selection is occurring against non-matching WMV types in established infections. WMV 2, 2+6, 2+8, and 4+8 are particularly notable in this respect. The converse behaviour seems to apply to WMV 2+6+8, which was also observed to have a general selective advantage in conventional samples (Table 7).

In Figure 1, the total frequencies of WMV 2, 4, 8 and 2+6 at various locations in UK are shown as histograms. The shaded parts of Fig. 1 represent the major cereal growing areas. WMV 2, as expected, showed high pathogenicity throughout the country. WMV 4, however, showed relatively low pathogenicity in East Anglia and the Midlands becoming higher only in the north-east. Whether this corresponds with a particular grower preference for Armada (WMR 4) in this area remains to be seen. Sporadically high and low levels of WMV 4, 8 and 2+6 in western areas is thought to be due to sampling error since cereals are not common in those parts. WMV 8 and 2+6 showed apparently complementary behaviour at most locations, confirming previous conclusions (Bennett, 1980). WMV 2+6 occurred with high pathogenicity in East Anglia, possibly coinciding with growers' preferences for locally produced cultivars.

3. Mixture trial samples

Tables 10 and 11 show results of analysis of leaf samples from large plot (0.1 ha) mixture trials at Fowlmere, Cambs., and PBI respectively. Despite large differences in epidemic development at the two sites, the pattern of results is similar. The most notable difference between these samples and those from pure stands of commercial crops (Table 7) is the relative rarity of complex pathogenicity. Furthermore, when it did occur, it was not confined to samples from mixed plots. Pairwise WMV combinations, except WMV 4+8, had quite high pathogenicity in pure plot populations, as did the WMV 2+6+8 combination, effects also observed in other sets of samples (Tables 7 & 9). Mixed plots sometimes generated populations with a high frequency of the matching two-way and three-way WMV type. This did not occur routinely, however, and it is notable that in Table 11 the most complex spectrum of WMV combinations was not generated by the most diverse mixture (4, 8 & 2+6) but by the least diverse one (three 2+6 cultivars).

Table 10. Observed mean pathogenicity values of combinations of WMV 2, 4, 8 and 2+6 in samples taken from pure and mixed trial plots at Fowlmere in July 1980

WMR group of source cultivar	Number of Cultivar plots	Total frequencies from primary test				Mean pathogenicity values of WMV combinations										
		2	4	8	2+6	2	4	8	2+6	2+4	2+8	4+8	8 + 2+6	4 + 2+6	2 + 4+8	4+8 + 2+6
Pure 0	2	83	3	74	35	48	2	74	35	1	0	1	0	0	0	0
2	2	100	12	76	17	0	0	0	9	7	89	4	8	0	2	0
4	1	82	71	29	0	24	0	0	0	20	0	3	4	0	62	0
2+6	3	100	19	84	97	25	3	36	41	0	0	6	38	6	0	12
Mixed 0 & 2+6	1	81	0	94	75	0	0	13	1	0	7	0	74	0	0	0
2 & 2+6	1	88	0	13	100	1	0	13	87	0	0	0	13	0	0	0
0, 2 & 2+6	1	100	7	100	13	83	3	0	0	4	0	0	100	0	0	0
2 & 8	1	58	0	76	7	0	0	19	7	0	57	0	0	0	0	0
2, 4 & 8	1	100	100	100	14	0	7	10	0	44	25	0	16	0	49	0
0, 2 & 8	1	100	0	85	8	0	0	0	8	0	100	0	0	0	0	0

Table 11. Observed mean pathogenicity values of combinations of WMV 2, 4, 8 and 2+6 in samples taken from pure and mixed trial plots at PBI in July 1980

WMR group of source cultivars		Number of cultivar plots	Total frequencies from primary test				Mean pathogenicity values of WMV combinations										
			2	4	8	2+6	2	4	8	2+6	2+4	2+8	4+8	8 + 2+6	4 + 2+6	2 + 4+8	4+8 + 2+6
Pure	0	1	77	1	-*	0	-	1	-	0	0	-	0	0	0	0	0
	2	1	82	0	32	86	0	0	0	67	0	56	0	19	0	0	0
	4	1	100	100	100	24	-	0	-	-	-	-	-	-	-	-	-
	8	2	46	4	58	24	3	0	23	0	16	2	1	31	0	1	0
	2+6	3	92	0	42	94	0	0	0	52	1	1	0	42	0	0	0
Mixed	0, 2 & 2+6	1	100	0	33	100	-	0	-	-	0	-	0	-	0	0	0
	0, 8 & 2+6	1	30	0	100	30	0	0	70	30	0	30	0	0	0	0	0
	2, 8 & 2+6	1	100	8	100	100	9	8	9	0	0	0	0	100	0	0	0
	2, 8 & 2+6	1	72	0	45	71	2	0	42	67	0	0	0	4	0	0	0
	4, 8 & 2+6	1	100	25	75	75	-	10	0	0	<3	37	0	63	-	0	0
	2, 4 & 8	1	52	100	93	19	0	0	0	10	50	27	100	9	0	0	0
	(2+6) x 3	1	57	51	54	100	32	42	15	33	0	0	0	16	30	14	21

* Result missing

Although analysis of populations from mixed cultivar plots reveals that matching WMV combinations may be selected for at fairly high relative frequencies, it should be remembered that the total infection on mixed plots was often much lower than that on pure plots. Thus the absolute numbers of complex pathogen genotypes in populations on mixed plots may be quite low.

Replicated results in Table 12, from samples taken from seedlings of the susceptible cv. Minister exposed in pure and mixed plots on five dates (see Table 13), confirm conclusions from Tables 10 & 11. The strong selection pressure for WMV 4 in pure plots of Armada (WMR 4) often outweighed that in mixed plots containing Armada, which may account for the generally greater complexity of populations from pure Armada plots. The same is true, but to a lesser extent, of the behaviour of WMV 2+6. Again WMV 2+6+8 was common, confirming other survey results (Tables 7, 9, 10 & 11). This is in conflict with previous survey work (Bennett, 1980) which has shown that WMV 8 and 2+6 often act in opposition in populations and some benefit from mixing and diversifying among WMR 8 and 2+6 cultivars may be expected. This change may have come about in 1980 owing to increasing areas of WMR 8 and 2+6 cultivars being grown.

Total frequencies of WMV 2, 4, 8 and 2+6 in the PBI mixture trial plots were also measured repeatedly during the season by scoring infection on exposed seedlings of matching WMR groups (Table 13a & b). The selection of WMV 2 and 4 in matching pure plots occurred as the season progressed (Table 13a). WMV 8 and 2+6 were frequent in matching pure plots from the start of the season. In non-matching pure plots, only WMV 4 appeared to be consistently selected against, with WMV 2+6 selected against only in the early part of the season. In mixture plots (Table 13b) a similar pattern was observed except that WMV 4 maintained a low frequency until July when it only increased in one mixture containing Armada. Thus there did not seem to be a tendency for mixed plots to generate more or less complex populations than their components growing in pure stands. It should be noted, however, that disease developed late in this trial and external sources of inoculum for the mobile nurseries cannot be ruled out.

Table 12. Observed mean pathogenicity values of combinations of WMV 2, 4, 8 and 2+6 in samples taken from seedlings of Minister exposed in pure and mixed trial plots at PBI during May and July 1980

Source Plot	WMR group	No. of exposures	Total frequencies from primary test				Mean pathogenicity values of WMV combinations										
			2	4	8	2+6	2	4	8	2+6	2+4	2+8	4+8	8 + 2+6	4 + 2+6	2 + 4+8	4+8 + 2+6
Hobbit (HO)	0	8	91	19	80	68	0	8	25	30	9	15	2	38	0	0	0
Bounty (BO)	2	7	79	24	82	50	0	1	16	29	8	34	6	19	2	7	0
Armada (AR)	4	7	88	96	72	34	6	1	0	16	0	0	20	8	8	65	2
Flanders (FL)	8	7	76	25	85	39	3	14	26	17	0	36	4	13	9	6	0
M. Huntsman (MH)	2+6	7	98	34	60	88	0	0	21	49	32	0	8	27	9	1	3
BO/AR/FL	2, 4 & 8	5	81	12	71	39	0	10	0	34	0	71	1	2	3	0	0
AR/FL/MH	4, 8 & 2+6	5	86	41	89	40	0	0	18	17	27	29	13	23	0	6	0

Table 13. Colony numbers occurring on seedlings of Bounty, Armada, Aquila and Maris Huntsman when placed in trial plots at PBI, expressed as percentage of colony number occurring on seedlings of Minister

a) pure plots

a) Exposure dates	No. of replicate plots	Test cultivar	WMR of test cultivar	Source plot and WMR group: Hobbit (HO) 0	Bounty (BO) 2	Armada (AR) 4	Flanders (FL) 8	Aquila (AQ) 8	M. Huntsman (MH) 2+6	Kinsman (KI) 2+6	Brigand (BR) 2+6
25 - 30 April	1	BO	2	195	0	78	150	126	105	167	140
		AR	4	19	0	12	14	9	0	10	8
		AQ*	8	107	100	62	79	144	20	120	108
		MH	2+6	82	102	13	102	46	41	245	85
13 - 16 May	1	BO	2	323	96	63	75	123	120	78	120
		AR	4	24	26	19	18	17	22	26	8
		AQ	8	304	55	55	97	128	77	69	57
		MH	2+6	115	66	50	26	18	87	82	48
20 - 22 May	1	BO	2	110	-	106	104	116	199	155	172
		AR	4	22	-	108	29	21	25	15	35
		AQ	8	84	-	82	177	119	110	76	112
		MH	2+6	47	-	48	59	77	90	102	76
28 - 30 May	3	BO	2	93	206	106	96	78	99	80	99
		AR	4	19	6	86	6	16	13	9	10
		AQ	8	91	117	67	118	125	100	81	60
		MH	2+6	71	69	49	47	47	90	60	87
2 - 4 July	3	BO	2	117	116	135	153	157	163	131	143
		AR	4	17	50	156	37	27	24	18	13
		AQ	8	85	93	110	130	156	126	57	83
		MH	2+6	73	75	38	59	54	90	79	84

*Aquila was used instead of Flanders as the WMR 8 differential because the seed stock of Flanders was of doubtful purity

Table 13. Colony numbers occurring on seedlings of Bounty, Armada, Aquila, and Maris Huntsman when placed in trial plots at PBI, expressed as percentage of colony number occurring on seedlings of Minister

b) mixed plots

b) Exposure dates	No. of replicate plots	Test cultivar	WMR of test cultivar	Source plot and WMR group: HO/BO/BR 0, 2 & 2+6	HO/AQ/KI 0, 8 & 2+6	BO/FL/BR 2, 8 & 2+6	BO/AQ/BR 2, 8 & 2+6	AR/FL/MH 4, 8 & 2+6	BO/AR/FL 2, 4 & 8	MH/KI/BR (2+6) x 3
25 - 30 April	1	BO	2	335	90	151	128	386	366	126
		AR	4	0	0	32	15	22	48	7
		AQ*	8	347	207	189	197	192	275	59
		MH	2+6	82	161	170	86	79	307	166
13 - 16 May	1	BO	2	113	81	190	65	209	267	111
		AR	4	29	11	13	8	39	32	22
		AQ	8	346	78	119	46	118	256	96
		MH	2+6	0	52	.31	7	37	91	68
20 - 22 May	1	BO	2	54	179	155	151	163	99	78
		AR	4	13	44	46	29	11	61	12
		AQ	8	91	204	123	171	126	121	93
		MH	2+6	70	117	115	105	117	31	112
28 - 30 May	3	BO	2	60	73	84	130	68	131	109
		AR	4	8	12	12	18	14	30	8
		AQ	8	40	92	85	121	44	74	83
		MH	2+6	43	39	82	47	53	68	99
2 - 4 July	3	BO	2	185	120	95	153	70	207	173
		AR	4	19	9	29	6	31	107	9
		AQ	8	124	96	71	100	57	136	91
		MH	2+6	79	83	62	84	77	72	99

*Aquila was used instead of Flanders as the WMR 8 differential because the seed stock of Flanders was or doubtful origin

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YELLOW RUST OF WHEAT

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Frequencies of virulence for the overall resistances WYR 1 to WYR 10 were similar in 1980 to previous years. The results of adult plant tests carried out in Polythene tunnels have shown that the cultivars Abele and Baron possess additional resistance that is absent in Clement and Stuart (WRY 9). Take-all was severe in some tunnels in 1980. Experiments have shown that it can be controlled by an application of MeBr gas to the soil, but that this treatment also causes a 'yellow striping' symptom of the upper leaves after anthesis. Prospects for controlling take-all in the long and short term are discussed.

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 1980 isolates

A total of 35 samples were received by post during 1980. This is similar to 1977 (39 samples) but less than 1978 (168 samples) or 1979 (52 samples). The 1980 samples had been collected in a non random way from Hobbit (4 samples), Kador (4), Mardler (3), Prince (3), Maris Huntsman (3) and 12 other cultivars. Isolates were made from 20 samples; 14 samples failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Sappo; the remaining isolate was lost due to growth chamber failure.

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

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 1979 and control isolates

Sixteen isolates and an isolate mixture were tested for virulences compatible with both overall and adult plant resistance using the Polythene tunnel technique described by Priestley & Byford (1978). Tussocks of 36 cultivars were sown on 1-2 November 1979, inoculated on 5 March and 26 March 1980, and assessed for percentage leaf area infection using the International Scale (Doling, 1967) on 22 May (GS 50-68), 5 June (GS 64-75) and 19 June (GS 75-85).

The isolates comprised eight controls of known virulence, seven collected in 1979 from plants with a greater than expected disease level, one from an inoculated plot and a mixture of a number of other 1979 isolates (Table 2). Plants in two tunnels were inoculated with isolate 76/71 to measure between-tunnel variation. These are referred to as 76/71A and 76/71B in later Tables.

Table 2. Isolates used in adult plant tests

Code	Cultivar[+]	Region[/]	Site	WYV factors*
Control isolates				
72/852	Maris Ranger	EM	Market Harborough	WYV (2),3,4,6
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	Sc	Mains of Ravensby	WYV 1,2,3
77/26	Hobbit	EM	Tydd St Mary	WYV 1,2,3
78/131	Venture	EM	Kelstern	WYV 1,2,3
78/138	Kador	WM	Pershore	WYV 1,2,3
78/150	Mega	E	Morley	WYV 2,3,4,6
1979 isolates				
79/4	Maris Templar	E	Belchemp, Suffolk	WYV 1,2,3
79/6	Hobbit	E	Barnham, Suffolk	WYV 1,2,3
79/9	Kador	SE	Oxon	WYV 1,2,3
79/11	Wizard	E	Trumpington, Cambs	WYV 2,3,4,6
79/18	Armada	SE	Eddlesborough, Bucks	WYV 2,3,4,6
79/20	Kador	E	Thaxted	WYV 1,2,3
79/31	Harvest Queen	EI	Leixlip, Co Kildare	WYV 1,2,3
Other isolates				
PBI 75/27	Hobbit inoculated with YRW 72/23			WYV 2,3,4
mix	Mixture of 1979 isolates			

\+ cultivar from which isolates were collected

( ) partially virulent on corresponding resistance

* virulence compatible with overall resistances (WYR 1-10) shown only

/ EM, East Midlands; WM, West Midlands; Sc, Scotland; E, East; SE, South East; EI, Eire

Table 3. Virulence factor frequency (%)

WYV factor	Common name	1976	1977	1978	1979	1980
WYV 1	Chinese 166 virulence	92	73	73	83	95
WYV 2	Heine VII virulence	100	100	97	100	100
WYV 3	Vilmorin 23 virulence	100	100	100	100	85.
WYV 4	Hybrid 46 virulence	12	24	27	17	15
WYV 5	T. spelta album virulence	0	0	0	0	0
WYV 6	Heine Kolben virulence	4	16	26	17	25
WYV 7	Lee virulence	0	8	0	0	0
WYV 8	Compair virulence	2	4	0	0	0
WYV 9	Riebesel 47/51 virulence	6	0	0	0	0
WYV 10	Moro virulence	0	0	0	0	0
	number of isolates tested	52	26	66	30	20

VIRULENCE TEST RESULTS

Seedling tests with 1980 isolates

Sampling was not carried out on a random basis and thus the virulence frequencies shown for 1976-80 (Table 3) should be interpreted with caution. Comparable data for the period 1970-75 have been described by Priestley & Byford (1976). The frequencies of individual virulence factors were broadly similar to previous years again confirming the view postulated earlier (Priestley & Byford, 1979) that the UK population of P. striiformis has reached a relatively stable position relative to WYR 1 to WYR 10. The frequency of WYV 3 in 1980 (85%) was lower than in any year since 1970, although it should be borne in mind that the 1980 frequency is calculated from a relatively small number of isolates.

Adult plant tests with 1979 and control isolates

The results of the adult plant tests are given (Table 4). Take-all was severe in some tunnels and it was noticeable that senescence occurred much earlier than in previous years.

Infection levels were generally lower than in previous years although, exceptionally, levels on the cultivar Michigan Amber were higher than previously. In view of the low disease levels, a multivariate analysis of infection levels (Priestley & Byford, 1979) was not carried out. Instead, cultivars and isolates have been grouped on the basis of the results of past tests (Table 4). Several

well-established compatible interactions between cultivars and isolates failed to produce the high infection levels found in previous years. These include Maris Templar (WYR 1) inoculated with isolates 78/138, 78/131 and 77/26, Maris Beacon (WYR 4) inoculated with isolates 75/109 and 78/150, and cultivars possessing WYR 12 inoculated with 72/852.

The results of seedling tests showed that Abele, Baron, Clement and Stuart all possess WYR 9. However, the adult plant tests suggest that isolate 76/15, which caused relatively high infection levels on Clement and Stuart, was unable to infect Abele or Baron, indicating that these two cultivars possess additional resistance absent from Clement and Stuart.

INVESTIGATION INTO CAUSE OF 'YELLOW STRIPING' LEAF SYMPTOM

Symptoms of take-all were first seen in wheat plants grown in Polythene tunnels in 1977. The disease was found to be well controlled by the application of methyl bromide gas to the soil after harvest, but casual observations showed that some wheat plants grown in the soil after treatment were showing a yellow striping of the upper leaves shortly after ear emergence.

Experiments carried out during 1980 have shown that the amount of striping was greater in plants grown in soil treated with methyl bromide than in untreated control soil. Cultivars differed significantly in the amount of striping when grown in treated soil and the concentration of bromide in both soil and leaf tissue was found to be increased by the methyl bromide treatment.

In the light of these results, a decision has been taken not to continue with the use of methyl bromide to control take-all and various soil rotation techniques are being investigated as an alternative strategy. In the long term, a mobile tunnel is being developed which could be moved to permit rotation. In the short term, soil is being replaced but this is a costly exercise. Full details of the experimental work will be published elsewhere.

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Table 4. Results of adult plant tests, 1980

Values are mean percent leaf area infection.

Isolate		79/20	78/138	79/31	78/131	76/71A	76/71B	
WYV factors		1,2,3	1,2,3	1,2,3	1,2,3,13	1,2,3,13	1,2,3,13	1,2,3
Cultivar	WYR factors							
Virtue	1,13	1	0	0	10	7	14	
Maris Huntsman	2,13	0	0	0	0	0	7	
Mardler	1,2,13	0	0	1	0	3	4	
Hustler	1,2,13	0	0	1	8	2	4	
Hobbit	14	0	1	0	0	0	6	1
Kador	14	0	0	0	0	0	2	
Maris Bilbo	14	12	11	1	12	5	20	
Brigand	2,14	1	0	0	2	0	3	
Clement	9	0	0	0	1	0	0	
Stuart	9	0	0	0	0	0	0	
Abele	9	0	0	0	0	0	0	
Baron	9	0	0	0	0	0	0	
Maris Freeman	6	0	0	0	1	0	0	
Maris Ranger	6	0	0	0	0	0	0	
Kinsman	6	0	0	0	0	0	0	
Norman	2,6	0	0	0	1	0	1	
Armada	12	0	0	0	0	0	0	
Mega	var,12	0	0	0	0	0	0	
Bounty	1	0	0	0	0	0	0	
Flanders	1,var	0	0	0	0	0	4	
Galahad	1	0	2	0	0	0	1	
Maris Templar	1	4	0	0	2	0	6	
Sportsman	1	0	0	0	0	0	3	
Avalon	4	0	0	0	0	0	1	
Maris Beacon	4	0	0	0	0	0	0	
Sentry	4	0	0	0	0	0	0	
Wizard	4	0	0	0	0	0	0	
Rapier	2,4	0	0	0	0	0	0	
Aquila	var	0	0	0	0	0	0	
Maris Fundin	var	0	0	0	1	0	2	
Mithras	x	0	0	0	0	0	1	
Axel	0	4	2	0	6	3	8	
Cappelle-Desprez	0	0	0	0	2	0	3	
Prince	0	0	0	0	0	0	2	
20A	0	0	0	0	1	0	3	
Michigan Amber	0	35	29	21	61	33	67	3

* = Michigan Amber sown by mistake in place of Prince.

PRIESTLEY, R H & BYFORD, P (1978) Yellow rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1977 Annual Report, 3-11.

PRIESTLEY, R H & BYFORD, P (1979) Yellow rust of wheat. United Kingdom Cereal Pathogen Virulence Survey 1978 Annual Report, 14-24.

APPENDIX

Identification of isolates from the UK and Eire section of the International Survey of Factors of Virulence of Puccinia striiformis

No samples were received during 1980.

BROWN RUST OF WHEAT

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Twenty nine samples of wheat brown rust were received in 1980. Isolates of Puccinia recondita were made from these samples and tested on seedlings of 33 cultivars under both a low (10°C) or a high (25°C) temperature regime. The resistance of most cultivars was expressed at both temperatures, but a few possessed types of resistance expressed only at only one or other temperature. Tests of adult plants with selected isolates of P.recondita were carried out in field nurseries and Polythene tunnels. Analysis of these results and those obtained previously has enabled cultivars to be grouped together on the basis of their specific resistances. A few cultivars have resistance which is apparently non-specific.

TESTS AT THE WELSH PLANT BREEDING STATION

Seedling tests with 1980 isolates

Thirty samples of wheat brown (leaf) rust (Puccinia recondita Rob. & Desm. f.sp tritici Erikss & Henn.) were received, mainly from the west midlands and eastern England. All samples were from winter wheats except one from rye. The majority of samples were from Maris Huntsman (7), Brigand (4) Mardler (3) and Prince, Kador and Armada (2 each). One sample came from each of ten other cultivars. The 29 isolates from wheat were all successfully cultured but the isolate from rye failed to infect wheat. Each isolate was tested on a set of 33 winter cultivars relevant to UK agriculture, plus the spring cultivar Sappo. Tests were carried out on seedlings using standard inoculation and assessment procedures. Each isolate was tested under two different post-inoculation temperature regimes.

Low temperature: 10°C constant temperature. 16h photoperiod.

High temperature: 25°C constant temperature. 16h photoperiod.

For each isolate, two sets of differential cultivars were grown in a spore-proofed glasshouse, inoculated in a settling tower, incubated in a dark, dew chamber at 15° for 16h and then transferred, one to the high and the other to the low temperature regime. Reaction types were assessed at intervals up to the time of full symptom expression.

Cultivars susceptible to all 29 isolates at the seedling stage are given below:

Maris Huntsman	Bounty	Maris Bilbo
Hustler	Maris Freeman	Maris Templar
Mardler	Arminda	Maris Ranger
Copain	Brigand	Aquila
RPB 48-75	Kinsman	Sportsman
Kormoran		

In addition, Prince was susceptible to the 23 cultures to which it was tested, as was Roazon to the 18 cultures to which it was tested. Rapier was susceptible to all six isolates tested.

Virtue and Avalon were susceptible to all but isolate WBRS-80-15 to which both gave an intermediate response at both temperatures.

Clement virulence was detected in only four isolates and these also overcame the resistance of Stuart, Baron and Abele. Stuart is known to carry the same resistance as Clement which is derived from rye (WBR-1) and it can be inferred that Baron and Abele also carry this resistance.

The remaining ten cultivars showed a temperature sensitivity of response to avirulent isolates. The spring cultivar Sappo was unique in that resistance was expressed at 10° and not at 25° to a number of isolates. Virulence at low temperature was detected in two isolates. In the other nine cultivars, resistance when effective was expressed at high temperature and not low. Virulence to Sterna and Sabre was not detected in any of the 29 isolates. Previous evidence of their similarity of response suggests that they possess the same resistance factor(s).

Five isolates carried virulence for Hobbit, Wizard and Norman and these cultivars were resistant at 25° to the remaining isolates. The latter two cultivars are derived from Hobbit which suggests that they have a common resistance.

The other three cultivars tested, Maris Fundin, Swan and RPB 765-78D, behaved similarly to Hobbit but the responses were not so clear cut.

Adult plant tests in field nurseries

Three isolation nurseries were grown in the 1979-1980 season, each consisting of 31 cultivars replicated three times. Each nursery was inoculated with a different isolate of P.recondita:

Isolate 74/2	Huntsman (WBR 5) virulent
Isolate 77/22	Clement (WBR 1) virulent
Isolate 79/4	Widely virulent isolate from 1979 survey

Assessments of percentage infection and reaction type were made on three occasions. A summary of the results is given in Table 1.

The susceptible cultivars grouped at the bottom of Table 1 are ranked in order of susceptibility from the relatively resistant Bouquet, Atou and Flinor to the highly susceptible Prince, Armada and Granta.

The remaining cultivars have been grouped in Table 1 according to their known or purported resistance composition. Clement, Aquila, Baron and Abele responded similarly being susceptible to 77/22 and 79/4 but resistant to 74/2.

Wizard, Norman and Hobbit responded similarly to each other being moderately resistant to all three isolates although Wizard was slightly more susceptible than the other two.

Maris Huntsman, Mardler and Brigand which are believed to carry the same resistance (WBR 5) were similarly susceptible to all isolates.

The group of cultivars resistant to all isolates included Bounty, Virtue, Avalon, Sportsman, Hustler and MMG 11569/83/1/2.

Mithras, Galahad, Kinsman and Sentry responded similarly to the three isolates although differences can be observed.

The race specific resistance of Maris Ranger was confirmed and the corresponding virulence is carried by isolates 77/22 and 79/4.

TESTS AT THE NATIONAL INSTITUTE OF AGRICULTURAL BOTANY

Seedlings and adult plants of 36 wheat cultivars were inoculated with 6 isolates of P.recondita (Table 2).

The seedling tests were carried out in controlled environment conditions (16h day at 18°C, 8h night at 11°C); the adult plant tests were carried out in Polythene tunnels. Plants were sown on 1-2 November 1979 and inoculated on 5 March, 26 March and 15 April 1980. Infection levels were assessed on 22 May (GS 58-68), 5 June (GS 68-71), 19 June (GS 75) and 3 July (GS 85).

Table 1. Results of adult plant tests in WPBS isolation nurseries, 1980

Cultivar	Isolate 77/22	79/4	74/2	$\bar{x}$
Clement	15.6 S	3.7 S	2.1 MR	
Aquila	10.6 S	5.4 S	2.1 MR	
Baron	4.4 MS	4.0 MS	0.6 R	
Abele	3.6 MS	2.6 MS	0.2 R	
Wizard	7.8 MS	5.2 MS	6.2 MS	
Norman	2.9 MR	2.1 MR	1.6 MS	
Hobbit	5.0 MR	3.8 MR	4.1 MR	
Maris Huntsman	11.8 S	7.9 S	7.9 S	
Mardler	14.0 S	4.3 MS	8.8 MS	
Brigand	11.2 S	4.2 MS	8.8 MS	
Bounty	1.5 MR	0.1 R	0.3 R	
Virtue	0.3 MR	0.1 R	0.4 R	
Avalon	1.2 MR	1.2 MR	0.5 MR	
Sportsman	1.0 R	0.5 R	0.8 R	
Hustler	0.5 R	0.0 R	0.3 R	
MMG 11569/83/1/2	0.1 R	0.1 R	0.4 R	
Mithras	3.9 MR	1.9 MR	2.0 MS	
Galahad	5.4 MS	4.4 MS	4.0 MS	
Kinsman	6.4 MR	3.1 MR	1.2 R	
Sentry	7.3 MS	2.9 MS	4.9 MS	
Maris Ranger	12.6 S	4.1 MR	1.5 R	
Bouquet	10.5 S	3.1 S	6.9 S	6.8
Atou	10.9 S	5.3 S	7.4 S	7.9
Flinor	12.2 S	5.1 S	6.4 S	7.9
Maris Freeman	12.0 S	5.7 S	8.0 S	8.6
Copain	15.3 S	5.6 S	6.7 S	9.2
Cappelle Desprez	12.9 S	8.7 S	6.7 S	9.4
Prince	14.2 S	7.8 S	7.9 S	9.9
Armada	16.2 S	7.1 S	9.4 S	10.9
Granta	17.2 S	8.9 S	7.3 S	11.1

Values are mean percent leaf area infection from 3 replicate plots assessed on 3 dates. S = Susceptible, MS = Moderately susceptible, MR = Moderately resistant, R = Resistant.

Table 2. Isolates used in tests

Code	Cultivar	Region*	Site	WBV factors
74/2+	Maris Huntsman	E	Morley	WBV 5
74/11+	Maris Fundin	SW	Seale Hayne	WBV 2
76/28+	Sappo	Ei	Leixlip	WBV 2
77/9+	Maris Ranger	W	WPBS nursery**	WBV 1,2
77/22+	Aquila	E	North Coates	WBV 1
78/A4	Bounty	E	NIAB tunnel***	WBV 2

+Supplied by Welsh Breeding Station

*E = East; SW = South West; Ei = Eire; W = Wales

**Plot inoculated with isolate 76/1

***Plot inoculated with isolate 77/9

Results

The results of the tests are given in Table 3. All seedling reactions were susceptible except those shown as R (resistant) in the table. Adult plant infection levels were generally low and differed widely between tunnels, partly due to patches of take-all in some tunnels (Priestley, Bayles & Crofts, 1981). Because of these large differences between tunnels, mean infection levels of individual cultivars within a tunnel have been expressed as a percentage of the amount of disease on the most severely infected cultivar within that tunnel. These low levels make interpretation of results difficult. However, the results confirm the earlier postulations (Priestley, Jones & Clifford, 1980), that isolates virulent on Clement and Stuart are also virulent on Aquila (Box A), but that the resistance of Aquila is not expressed at the seedling stage. Abele and Baron have resistance that is similar to Clement and Stuart at the seedling stage, but at the adult plant stage Abele and Baron appear to have additional resistance effective against isolates 77/22 and 77/9. The results also confirm that isolates virulent on Maris Huntsman (WBR 5) are also virulent on Mardler and Brigand (Box B).

The resistance of Wizard, Norman and Hobbit was similar to that of Maris Fundin (WBR 2) at the seedling stage. However, at the adult plant stage there appeared to be differences between these cultivars. Maris Templar also behaved differently to the other four cultivars both in the seedling and adult plant tests. Further tests are necessary to resolve the relationships between these cultivars.

Table 3. Results of seedling and adult plant tests at NIAB, 1980

Isolate	77/22		77/9		74/11		76/28		78/A4		74/2	
Cultivar	WBV 1		WBV 1,2		WBV 2		WBV 2		WBV 2		WBV 5	
Clement	34		5		0	R	1	R	5	R	1	R
Stuart	55	A	4		0	R	0	R	0	R	6	
Aquila	59		10		0		0		0		0	
Abele	0		2		0	R	0	R	0	R	0	R
Baron	0		0		0	R	2	R	11	R	0	R
Maris Bilbo	0		7		2		77		41		1	
Maris Templar	4		41		23		2		0		0	
Maris Fundin	7	R	18		4		17		55		0	R
Wizard	0	R	21		33		12		9		2	R
Norman	7	R	1		0		1		3		1	R
Hobbit	1	R	0		0		5		0		1	R
Maris Huntsman	3		0		0		6		2		11	
Mardler	16		19		1		16		12		79	B
Brigand	3		8		2		21		0		34	
Rapier	0		2		0		0		0		0	
Virtue	0		0		0		0		3		0	
Hustler	1		0		0		1		1		0	
Bounty	0		0		0		2		4		0	
Kinsman	0		6		0		0		0		0	
Mithras	1		0		0		3		0		9	
Cappelle - Desprez	3		10		0		2		0		2	
Avalon	12		2		1		5		0		0	
Mega	3		0		2		8		13		0	
Maris Ranger	3		8		0		4		12		1	
Sentry	8		1		0		4		4		16	
Sportsman	0		3		0		7		29		0	
Maris Freeman	1		6		4		26		4		5	
Galahad	0		9		0		24		2		23	
Prince	13		29		7		8		6		5	
Kador	18		7		1		21		7		55	
Armada	10		40		16		17		74		12	
20A	24		43		3		24		42		34	
Flanders	65		36		28		16		33		22	
Maris Beacon	44		39		12		23		18		82	
Axel	100		100		100		31		63		100	
Michigan Amber	89		71		56		100		100		86	
% infection on most susceptible cultivar	4.0		5.2		2.8		13.3		4.3		3.0	

Values are mean leaf area infection expressed as a percentage of the most severely infected cultivar

For explanation of boxes, see text.
R = resistance at seedling growth stage

INTERPRETATION OF TEST RESULTS

The determination of specific resistances possessed by cultivars is necessary for their rational deployment in agriculture through diversification schemes or the use of mixtures. Limitations on time and facilities often prevent classical genetical analysis of resistance relationships and it becomes necessary to characterise cultivars on the basis of their responses to particular isolates of the pathogen which differ in their specific virulences. It is this latter type of analysis that is carried out via the virulence surveys. In the wheat brown rust system, analysis is complicated by the variation in the expression of some resistances in relation to plant growth stage and environmental test conditions. Such test conditions need to be defined and standardised. Our current understanding of the relationships between the different cultivar resistances is summarised (Table 4) from the results of controlled environment studies reported here and previously, and various adult plant tests carried out in the field and in Polythene tunnels in the past. The resistance factor WBR 1 is of the overall or seedling type in most cultivars in which it occurs although in Aquila, resistance is only expressed in adult plants. The relationships between WBR 2 cultivars is not completely clear especially with regard to Maris Bilbo and Maris Templar. WBR 2 is expressed only at relatively high temperatures as opposed to WBR 3 which is expressed at relatively low temperatures. The relationship between WBR 3 and WBR 4 requires further study. Sabre appears to carry WBR 7, which is present in Sterna, although the evidence is not conclusive. The designation WBR 8 is proposed for the adult plant resistance of Maris Ranger which seems to be derived from the spring cultivar Peko. The relationships between the cultivars in the last group in Table 4 are not clear. They are all of the adult plant type and it is only the cultivars Virtue, Avalon, Hustler, Mithras, Galahad, Sentry and Rapier within this group to which corresponding virulence has not yet been detected.

To date, information on temperature sensitivity has only been obtained for resistances of the overall type and has been based on seedling test results. The effect of temperature on the expression of resistance at post seedling growth stages remain to be determined and such information could be of value in assessing resistance relationships between cultivars as has been done for overall resistances. In addition, it may be possible to define conditions under which adult plant resistance is expressed earlier in the growth of the plant as, for example, has been shown for oat crown rust (Clifford and Schafer 1966). This would be of considerable practical value because, at present, tests of isolates carrying 'new virulence' can only be carried out in the following season using

Table 4. Cultivars grouped according to their specific resistances

Resistance group	Cultivar	Year classified	Type of[+] resistance	Year virulence detected
WBR 1	Clement*	1977	Overall	1977[4]
	Aquila	1979	Adult plant	
	Stuart	1980	Overall	
	Abele	1981	Overall	
	Baron	1981	Overall	
WBR 2	Maris Fundin*	1977	Overall TS	1974[2]
	Maris Bilbo	1978	(Overall TS)	
	Maris Templar	1979	(Overall TS)	
	Wizard	1981	Overall TS	
	Norman	1981	Overall TS	
	Hobbit	1981	Overall TS	
WBR 3	Sappo*	1978	Overall TS	1973[1]
WBR 4	Maris Halberd*	1978	(Overall TS)	1973[1]
WBR 5	Maris Huntsman*	1977	Adult plant	1976[3]
	Maris Nimrod	1977	Adult plant	
	Mardler	1978	Adult plant	
	Brigand	1979	Adult plant	
WBR 6	Gamin*	1977	?	
WBR 7	Sterna*	1979	Overall TS	1977[4]
	(Sabre	1981)	Overall TS	
WBR 8	Maris Ranger*	1981	Adult plant	1978[5]
WBR ?	Sportsman	-	Adult plant	1979[6]
	Kinsman	-	Adult plant	(1980)[7]
	Bounty	-	Adult plant	(1980)[7]
	Virtue	-	Adult plant	
	Avalon	-	Adult plant	
	Hustler	-	Adult plant	
	Mithras	-	Adult plant	
	Galahad	-	Adult plant	
	Sentry	-	Adult plant	
	Rapier	-	Adult plant	

( ) Requires confirmation
* Type cultivar
\+ Overall and adult plant sensu Zadoks (1961).
T.S. Temperature sensitive. See text.

[1]Clifford (1974); [2]Clifford & Clothier (1975);
[3]Clifford, Jones & Priestley (1977): [4]Clifford, Jones & Priestley (1978)
[5]Clifford, Jones & Priestley (1979); [6]Priestley, Jones & Clifford (1980)
[7]This report.

adult plants grown in either Polythene tunnels or isolation nurseries. It would clearly be advantageous to carry out tests in the same year as the 'new virulence' was detected using seedling or juvenile plants. This could be a practical possibility if temperatures could be found at which adult plant resistance was expressed at the seedling stage.

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MILDEW OF BARLEY

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There were a few minor additions to the known resistance groups and pathogenicity factors. There was no pathogenicity for the cultivar Atem, but pathogenicity for Triumph (BMR 6 + Ab 12) was more common than in the previous two years.

The pathogen population structure on the major resistance groups of barley cultivars showed little change over the past three years. There was some tendency however, for recently selected pathogenicity characters to increase on cultivars with the longest exposed, non-matching resistance genes.

Use of the WIST (Wind Impaction Spore Trap) facilitated for the first time an analysis of overall frequencies of the major pathogenicity factors on a national and a regional basis. Regional distribution of pathogenicity closely followed expectation with BMV 3 more common in southern Scotland than elsewhere, and BMV 6 more common in eastern England than in the south-west of Scotland.

The overall national frequencies of pathogenicity factors coincided remarkably closely with the frequencies determined from the analysis of non-corresponding factors in the main survey. Deviations between the two sets of data provided evidence for a general cost of pathogenicity associated with BMV 4, and specific costs of pathogenicity associated with particular BMV combinations, such as BMV 5-6. Three combinations were more common than expected.

Detailed analysis of a pathogen population sample from the cultivar Keg showed that, over four pathogen generations, although there was no change in mean pathogenicity for the cultivar, the population distribution shifted towards greater adaptation to Keg.

Laboratory tests confirmed the marked insensitivity to triadimefon of some isolates collected from triadimefon-treated crops by Dr J T Fletcher (ADAS, Newcastle). The practical significance of these isolates is not yet known.

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, used previously, has several different meanings and connotations and may thus lead to some misinterpretation.

A total of 489 bulk isolates was received in 1980, of which 177 failed to establish. Table 1 shows the number of samples received from each cultivar, and the BMR group to which they belong.

New identifications

No new pathogenicity characters were identified (but see WIST section below). However, Dragon represents a new BMR group, as it combines M1g with M1a6 and M1v, as does Antler, which combines M1g with M1a.

Table 2 provides the complete data for the samples sent in during 1980 which have been tested so far. Isolates from recently introduced varieties with combined resistance factors again produced relatively few colonies on their corresponding seedling test cultivars. For Goldmarker isolates however, this discrepancy may have arisen through the use of Jupiter as a tester since it now seems that Jupiter and Goldmarker differ by at least one gene though they both possess BMR 3+4.

Numerous isolates were received from Triumph: those that were tested gave a high level of pathogenicity on Triumph itself. The resistance of this cultivar must now be at considerable risk. Most of the isolates from this cultivar came from Scotland, which probably accounts for the high frequency of BMV 3 among them. This is probably a sampling bias since the WIST data indicated that the highest pathogenicity for BMR 6 and Triumph occurred in eastern England.

WIST - the wind impaction spore trap

Determination of the overall frequency of pathogenicity in the country as a whole requires some form of remote sampling, as suggested and implemented by Dr E Schwarzbach and Mr E Limpert in Germany. To improve on the effectiveness of the 'Schwarzbach trap' for this particular purpose we designed, built and operated the Wind Impaction Spore Trap for use on a car roof, which allows a high rate of air flow over a large area of exposed seedling leaves. Healthy seedlings of wheat and barley were exposed in the trap for distances of 50 to 120 km, depending on the density of cereal production in the areas traversed. Long distance traverses were made during the late part of the growing season (Fig. 1).

Table 1. Number of samples received in 1980 and the BMR group definitions of the cultivars from which they were collected

BMR group	Gene	Cultivar and number of samples
0	-	Hoppel (1) Maris Otter (1) Golden Promise (23)
1	'Mlh' (2 genes)	Marko (1) Sonja (2) Gerbel (3) Athene (4) Igri (8) Video* (2) Hexa (1)?
2	Mlg (2 genes)	Julia (18)
3	Mla6	Midas (25)
4	Mlv (2 genes)	Aurea (5) Lofa Abed (19)
5	Mlas	Trojan (2) Hassan (18)
6	Mla 4/7 (2 genes)	Keg (7) Ark Royal (11) Wing (20)
7	Mla	Tyra (27)
8	Mla 4/9 (2 genes)	Simon (25)
2+4		Flare (7) Sundance (9) Georgie (9) Cerise (11) Koru (12)
2+5		Piccolo (1) Patty* (1) Porthos (5) Tintern (7) Athos (8) Erna* (12)
2+7		Antler* (8)
3+4		Jupiter (1) Goldmarker (28)
4+5		Egmont (28)
4+6		Claret (26)
4+?		Magnum (1)
4+?		Atem (21)
4+?		Kym (11)
6+Ab		Triumph (34)
2+3+4		Dragon* (10)
Blends and multilines		Blends (7) Grand Prix (6)
Unknown		Tenn 61.119 (1) Kennebar (1) Rode (1)
Rupal breeding line (1)		

*new identifications in 1980

Fig. 1. Distribution of BMV characters estimated by WIST survey, 1980

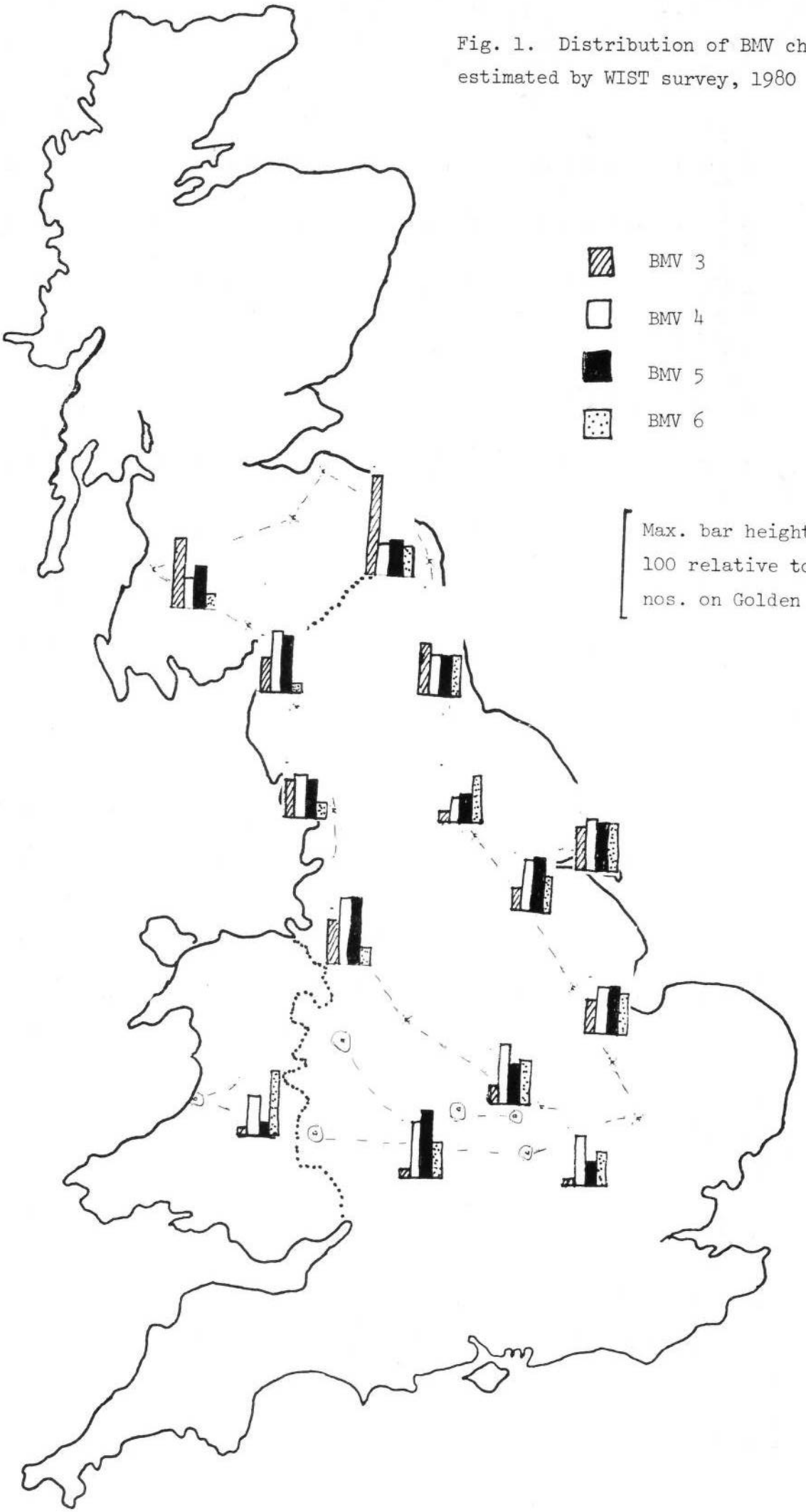

Table 2. Mean pathogenicity++ of bulk isolates on test seedlings of BMR group cultivars. Only isolates which were pathogenic on the cultivar from which they were collected are included, except where otherwise noted

BMR group	Source of isolate	Number of pathogenic isolates	BMV group of test seedlings##																
			1	2	3	4	5	6	7	8	2+3	2+4	2+5	2+5+?	2+6	3+4	4+5	4+6	6+Ab
0	Golden Promise	11	43	74	38	17	35	49	0	1	42	3	58	28	67	0	2	1	6
	Maris Otter	1	64	41	26	15	49	4	0	0	-	-	-	-	-	-	-	-	-
1	Gerbel	3	25	59	7	4	12	54	0	0	8	11	20	5	56	0	3	0	1
	Athene	3	33	70	32	5	32	41	32	0	38	5	10	3	69	0	1	0	9
	Igri	4	18	60	14	12	25	36	0	0	14	3	6	3	46	2	2	0	0
	Sonja	1	28	62	62	50	1	61	0	0	9	23	0	0	34	5	0	0	0
	Marko	1	56	60	23	11	20	49	1	0	48	1	35	33	75	0	0	0	0
	Video	2	19	78	22	12	11	20	0	0									
2	Julia	12	48	77	57	36	28	19	11	0	15	20	59	80	14	1	3	0	0
3	Midas	17	31	62	87	27	44	35	0	6	98	17	50	36	32	11	11	0	3
4	Lofa Abed	10	31	66	29	68	22	2	6	0	20	56	39	20	1	8	19	2	2
	Aurea	1	-	55	2	35	23	5	0	0	-	-	-	-	-	-	-	-	-
5	Trojan	2	21	73	0	4	121	1	0	0	1	0	67	34	0	0	0	0	0
	Hassan	12	31	83	25	26	67	12	0	0	22	11	74	51	1	1	9	1	2
6	Ark Royal	5	43	105	30	5	17	112	0	0	47	5	17	14	69	0	0	1	8
	Keg	3	45	65	22	2	16	84	0	0	20	5	12	8	103	0	0	0	12
	Wing	8	44	73	31	5	1	88	0	1	34	0	0	0	69	0	0	0	21
7	Tyra	18	31	71	14	6	41	23	79	5	7	7	42	46	9	0	4	0	5
8	Simon	12	34	68	2	8	14	76	0	66	0	0	20	16	55	0	0	1	2
2+4	Cerise	6	45	78	28	89	32	7	0	6	25	65	31	39	17	7	21	4	3
	Georgie	3	51	83	59	53	44	32	4	0	47	33	71	38	27	8	9	4	7
	Koru	4	47	75	57	63	35	2	0	0	19	48	58	37	0	8	37	0	0
	Flare	2	15	58	33	48	12	0	0	0	35	52	28	6	0	10	12	0	0
	Sundance	4	31	82	67	76	5	0	0	0	80	44	0	0	0	21	0	0	0

Table 2 (contd.)

2+5	Athos	1	41	85	0	19	47	14	0	0	0	3	68	57	1	0	1	0	0
	Porthos	2	51	78	0	6	62	26	0	0	0	2	77	69	19	0	0	0	0
	Patty	1	43	91	0	6	73	0	85	0	0	2	69	48	0	0	0	0	2
	Erna	9	42	74	30	16	60	5	6	0	44	16	73	67	7	3	7	1	8
	Tintern	1	31	160	0	18	127	1	0	0	1	0	57	85	1	0	1	0	0
2+7	Antler	7	35	62	38	14	36	13	89	0	55	14	51	25	12	8	1	1	3
3+4	Goldmarker	19	33	73	74	83	20	8	0	0	88	49	36	26	6	29	14	6	2
	Jupiter	1	31	68	89	90	103	0	0	0	-	-	-	-	-	-	-	-	-
4+5	Egmont	12	23	65	3	71	62	7	0	0	10	47	74	41	2	1	34	0	0
4+6	Claret	11	32	66	26	68	21	86	0	0	31	39	18	11	76	3	6	25	13
4+?	Kym	9*	23	69	19	64	34	8	9	0	34	46	52	35	9	8	11	11	0
6+Ab	Triumph	17+	50	70	47	3	2	86	0	1	100	2	1	1	106	1	0	1	89
2+3+4	Dragon	5	34	74	83	82	24	7	0	0	88	36	48	32	9	32	1	10	0
	Grand Prix	6*	28	63	4	23	31	57	0	58	8	20	36	49	57	0	20	4	2
	Hexa	1*	53	83	78	24	28	38	0	0	42	9	71	70	21	2	1	0	19
	Rupal Cross	1**	25	74	0	109	58	34	0	0	0	68	91	98	0	0	58	4	0
	Blend	2	42	79	15	12	28	1	67	0	20	19	36	20	36	5	3	8	2
	Bayleton	6	70	53	94	15	17	2	0	0	77	48	68	45	0	17	65	0	5

+ includes 4 single colony isolates

* not yet tested on host cultivar

** virulent on the breeding line, but not on Rupal or Rupee

++ See 1979 Report : mean colony number on test cultivar relative to that on Golden Promise in the same test.

The cultivars used were:

BMR group	cultivar
1	37/136, 41/145, Astrix
2	Goldfoil, Zephyr, Julia, Union
3	M. Concord, Midas
4	Vada, Lofa Abed
5	Sultan, Hassan
6	H.1063, Wing, Ark Royal
7	Tyra
8	Akka

BMR group	cultivar
2+3	Inis
2+4	Georgie
2+5	Aramir
2+5+?	M. Mink
2+6	Mazurka
3+4	Jupiter
4+5	Egmont
4+6	Claret
6+Ab	Triumph

From Fig. 1, BMV 3 is much more common in Southern Scotland, NW and NE England, and N. Humberside, than it is elsewhere. This is presumably due to the relative popularity of Midas, and other cultivars with BMR 3, in these wetter areas.

BMV 4 and 5 are generally common, though BMV 5 is infrequent in Wales, and there is no large scale selection for either character in Southern Scotland.

BMV 6 shows a converse distribution to that of BMV 3, being rather uncommon in the west of the country from the Midlands through to Southern Scotland. It is most commonly found in eastern England. Pathogenicity for Triumph (BMR 6+Ab12) shows a similar geographical distribution (see above).

The distributions of the common characters BMV 1 and 2, and the relatively rare characters BMV 7 and 8, are not shown since no obvious pattern is discernible.

The main barley growing area is along the eastern half of the country which presumably provides the largest contribution to the overall frequency of pathogenicity characters. A total of 49 tests from eastern samples was therefore averaged to give an indication of overall frequencies, covering the area from the east of southern Scotland to south of Cambridge. The data for single characters and combinations are summarised in Table 3.

Table 3. Mean pathogenicity values for individual and combined characters obtained by spore-trapping (WIST) in eastern England and Scotland

	BMV character									
Test cultivar	1	2	3	4	5	6	7	8	exp.	obs.
Inis		76	21						16	33
Sundance		76		41					31	31
Aramir		76			25				19	43
Jupiter			21	41					9	7
Egmont				41	25				10	14
Claret				41		33			14	4
Triumph						33				7
All samples (49)	40	76	21	41	25	33	4	1		

From Table 3, the mean of all samples provides for the first time an indication of the relative frequency of the major pathogenicity characters in the UK: the usefulness of this data is further explored below. The values for pathogenicity characters corresponding to cultivars with combined resistance characters generally followed expectation from the products of the appropriate single characters. However, pathogenicity for Inis and Aramir was considerably in excess of expectations using values derived from Julia (BMR 2), Midas (BMR 3) and Hassan (BMR 5). Subsequent tests with sub-samples from Inis showed that Julia and Midas each possess at least one resistance gene additional to BMR2 in Julia and BMR 3 in Midas. Similarly, Hassan was shown to possess at least one gene additional to the BMR 5 in Hassan and Aramir.

Integration of the WIST and the conventional surveys

Analysis of the data obtained in the conventional survey for corresponding and non-corresponding pathogenicity factors revealed only small differences between each of the last three years. The values were therefore averaged to give the data in the body of Table 4.

Table 4. Frequencies of corresponding and non-corresponding pathogenicity characters averaged for all sites over three years (1978, 79, 80) and compared with the overall frequencies obtained from the WIST survey (1980

Source cultivar	BMV character 1	2	3	4	5	6	7	8
BMR 0	47	67	41	19	28	33	2	1
1	42	67	24	13	21	42	3	0
2	40	76	45	21	27	19	4	2
3	45	62	73	19	33	32	1	0
4	29	61	22	66	23	3	2	0
5	40	75	15	13	67	9	0	0
6	47	74	20	5	15	87	0	4
7	42	71	19	6	41	22	74	2
8	56	64	3	3	16	82	0	85
mean*	43	68	24	13	28	23†	1	1
WIST mean	40	76	21	41	25	33	4	1
'self'	42	76	73	66	67	87	74	85

*excluding all 'self' values (i.e. those underlined).

†excluding value from BMR 8.

The WIST means give an integrated value for the average pathogenicity in the air spora against each of the BMR factors. BMV 2 is clearly the most common (76) and BMV 8 the least so (1). If there is no selection on one BMR group against any non-corresponding pathogenicity then in samples from each the pathogenicity values for each non-corresponding factor should simply reflect the overall pattern observed. This is demonstrated in the simple model below:

	Pathogenicity character			
	A	B	C	D
Overall frequency	90	60	30	10
Sample from A	100	60	30	10
B	90	100	30	10
C	90	60	100	10
D	90	60	30	100
mean of non-corr. pathogenicity	90	60	30	10

In the first line, the overall frequencies for each pathogenicity character are determined by the area occupied by the cultivar and its susceptibility. In the subsequent lines, the data represent the results obtained with samples from each cultivar. If there is no interaction between the resistance genes and non-corresponding pathogenicity characters, then in any sample of isolates from a particular cultivar, the pathogenicity for non-corresponding factors should occur with the same distribution as that observed in the overall sample.

Returning to Table 4 it can be seen that this relationship holds overall, with remarkable precision for BMV 1, 2, 3, 5, 7 and 8, by comparing the WIST means with those for non-corresponding pathogenicities. However, there is a large deviation for BMV 4, and a smaller deviation for BMV 6. These deviations indicate that relatively large quantities of spores are being produced by cultivars with, respectively, BMR 4 and BMR 6, but there is selection against these spores on cultivars with other BMR factors. This is particularly striking for BMR 4: all other BMR groups produce less BMV 4 than the amount expected from the WIST mean. In other words, there appears to be a general cost of pathogenicity to the fungus attached to possession of BMV 4.

The overall figures for non-corresponding pathogenicity factors conceal individual interactions. For example, it is consistently observed that BMR 5 cultivars select against BMV 6, and conversely that BMR 6 cultivars select against BMV 5. Thus, BMV 6 on BMR 5 has a value 9 compared with an expected 23 (or 33 from the WIST survey), and BMV 5 on BMR 6 has a value 15 compared with an expected 28 (or 25 from the WIST survey). The averages of these observed and expected values are respectively 12, 26 and 29 and these are entered in the appropriate lines in Table 5. For this pair of pathogenicity factors, there appears therefore to be a specific 'cost of pathogenicity'. Table 5 is arranged to show the appropriate values for all possible 2-way combinations of BMV factors.

The deviation (dev.) columns in Table 5 summarise the individual and overall effects. Of the total of 28 comparisons, 14 show no deviation, five show a positive deviation (BMV 1-6, 1-8, 2-3, 5-7 and 6-8), and 12 show a negative deviation (BMV 4 with all others; 6 with 2, 5 and 7, as well as 4; 3-8 and 5-8).

For diversification and mixture recommendations, it would appear best to select combinations for which the average pathogenicity values in Table 5 are low (less than 30), and in particular, those that show negative deviations, i.e. that occur at lower than expected values. For three cultivar mixtures, average pathogenicity values for the appropriate 3 pairs can be derived from Table 5, as in Table 7 from the 1979 Report.

Deviation and trends between years

The original data for Table 4 are given in Table 6 to show the individual pathogenicity values for each of the three years, 1978, 1979 and 1980. On the whole, the values changed little over the period. Unfortunately, a statistical test is not yet available to indicate the significance that may be attached to deviant values. The most obvious positive and negative deviations from average non-matching pathogenicity values, summarised also in Table 7, have been consistent, which increases the probability that they are real effects rather than sampling errors. Where trends are apparent, they are largely towards an increase in non-matching pathogenicity values (Table 7). Matching pathogenicity values showed no pattern of variation between years so they have been omitted from Tables 6 and 7 for simplicity.

Table 5. Average pathogenicity values for all 2-way combinations of BMV 1-8, compared with expected values from the overall means and from the WIST survey

BMV 1 with	obs.	exp.*	dev.	exp.†	dev.
2	54	55	.	58	.
3	35	33	.	31	.
4	21	28	−	41	−
5	30	35	.	33	.
6	45	33	+	37	+
7	23	22	.	22	.
8	28	22	+	21	+
	34	33		35	

BMV 2 with	obs.	exp.	dev.	exp.	dev.
1	54	55	.	58	.
3	54	46	+	49	+
4	41	41	.	59	−
5	51	48	.	51	.
6	47	46	.	55	−
7	38	35	.	40	.
8	33	35	.	39	.
	45	44		50	

BMV 3 with					
1	35	33	.	31	.
2	54	46	+	49	+
4	21	19	.	31	−
5	24	26	.	23	.
6	26	24	.	27	.
7	10	13	.	13	.
8	3	13	−	11	−
	25	25		26	

BMV 4 with					
1	21	28	−	41	−
2	41	41	.	59	−
3	21	19	.	31	−
5	18	21	.	33	−
6	4	18	−	37	−
7	4	7	−	23	−
8	3	7	−	21	−
	16	20		35	

BMV 5 with					
1	30	35	.	33	.
2	51	48	.	51	.
3	24	26	.	23	.
4	18	21	.	33	−
6	12	26	−	29	.
7	21	15	+	15	+
8	8	15	−	13	−
	23	27		28	

BMV 6 with					
1	45	33	+	37	+
2	47	46	.	55	−
3	26	24	.	27	.
4	4	18	−	37	−
5	12	26	−	29	.
7	11	12	.	19	−
8	(43)	(12)	(.)	(17)	(.)
	24	27		34	

BMV 7 with					
1	23	22	.	22	.
2	38	35	.	40	.
3	10	13	.	13	.
4	4	7	−	23	−
5	21	15	+	15	+
6	11	12	.	19	−
8	1	1	.	3	.
	15	15		19	

BMV 8 with					
1	28	22	+	21	+
2	33	35	.	39	.
3	3	13	−	11	.
4	3	7	−	21	−
5	8	15	−	13	−
6	(43)	(12)	(.)	(17)	(.)
7	1	1	.	3	.
	13	16		18	

*exp. derived from means of all non-corresponding pathogenicity values (Table 4)

†exp. derived from WIST survey mean values (Table 4)

Table 6. Non-corresponding pathogenicity values for each of the three years, 1978-1980

Source cultivar	Year	BMV character 1	2	3	4	5	6
BMR 0	'78	51	66	41	15	16	26
	'79	46	64	45	26	32	28
	'80	45	71	37	17	36	45
1	'78	-	83	23	9	24	40
	'79	-	53	25	18	18	44
	'80	-	65	22	11	20	41
2	'78	31	-	56	10	18	17
	'79	42	-	22	17	35	21
	'80	48	-	57	36	28	19
3	'78	58	69	-	15	27	32
	'79	45	59	-	18	29	28
	'80	31	62	-	27	44	35
4	'78	28	54	8	-	21	1
	'79	28	64	30	-	26	6
	'80	31	65	27	-	22	2
5	'78	46	76	6	9	-	9
	'79	43	66	18	7	-	8
	'80	30	82	21	23	-	10
6	'78	47	74	10	7	15	-
	'79	49	67	20	4	20	-
	'80	44	82	29	4	9	-
7	'78	43	75	22	8	36	28
	'79	51	66	22	3	47	15
	'80	31	71	14	6	41	23
8	'78	63	80	6	1	20	-
	'79	70	44	0	0	15	-
	'80	34	68	2	8	14	-
All	'78	46	72	22	9	22	22
	'79	47	60	23	12	28	21
	'80	37	71	26	17	27	25

From Table 7, it can be seen that positive deviations and trends towards increased pathogenicity tend to occur among more recently selected pathogenicity characters in populations on cultivars with the longest exposed resistance genes (BMR 0, 1, 2 and 3). Negative deviations tend to occur among more recently selected pathogenicity characters in populations on cultivars with more recently introduced resistance genes, for example, on BMR 8.

With the possible exception of the combination BMR 1-6, there are no examples of reciprocal positive deviations from average non-matching pathogenicity values. On the other hand, for the pairs BMR 4-6 and 5-6, non-matching pathogenicity is less than the overall average on both cultivar groups. In two instances, on BMR 3-5 and BMR 3-6, BMV 5 and 6 respectively have higher than average pathogenicity values on BMR 3, but BMV 3 has a lower than average value on both BMR 5 and BMR 6. However, both of these negative values appear to be tending back towards the average.

Assuming they are real, the trends that are occurring may be due to changes in cultivar frequency, for example, the increase in BMV 4 on BMR 2 and 3 may be due to increased use of cultivars in groups BMR 4, 2+4 and 3+4. They may also be due to pathogen adaptation, particularly since the pattern of positive changes appears to follow chronologically the length of exposure of particular BMR genes. Whichever explanation may be the more important, the practical outcome is the same: for diversification and cultivar mixtures it is best to concentrate on new cultivars with recently introduced resistance genes, particularly those that show a reciprocal negative deviation such as BMR 4-6 and BMR 5-6 (Tables 5, 6, 7).

Table 7. Summary of deviations and trends in non-corresponding pathogenicity values for the three years 1978-1980

Source cultivar	BMV character 1	2	3	4	5	6
0	..	..	+.	..	.↑	+↑
1	.	..	..	−.	..	+.
2	.↑	.	+.	+↑	..	..
3	.↓	..	.	+↑	+↑	+.
4	..	..	..	.	..	−.
5	..	..	−↑	..	.	−.
6	..	..	−↑	−.	−.	.
7	..	..	..	−.	+.	..
8	..	..	−.	−.	−.	.

. no deviation or trend +, − positive or negative deviation from the average
↑,↓ increasing or decreasing value over the period.

Adaptation within the pathogen population

In early June, approximately one hundred samples of E. graminis f. sp. hordei were collected from a heavily infected field of Keg (BMR 6) near Ely. Two samples were obtained from each of 50 plants, one from the oldest available leaf of the main tiller ('old' population) and one from the youngest available leaf on the youngest tiller ('young' population). It was estimated that the samples differed in age by four pathogen generations. Each was tested on detached seedling leaf segments of Keg and several different cultivars, with Golden Promise as a control.

The mean pathogenicity of the 'old' and 'young' populations on Keg itself was the same, but the characteristics of the population distributions changed markedly. In the 'old' populations, all samples were characterised as pathogenic on Keg, and were normally distributed about the mean with respect to skewness and kurtosis. The 'young' population however, showed marked positive skewness and kurtosis, indicating that selection had been both stabilising and directional, favouring isolates with pathogenicity around the mean level, but reducing the frequency of those with below average pathogenicity more than those with greater than average pathogenicity.

The number of isolates pathogenic on the differential cultivars BMR 3 (Midas), BMR 5 (Hassan) and BMR 6 + Ab 12 (Triumph) was the same in both 'old' and 'young' populations. However, there was a tendency for such isolates to be associated with above average pathogenicity for Keg in the 'old' population, and to be normally distributed in the 'young' population. This indicated selection against complex races relative to simpler races as the season progressed.

The mean pathogenicity of the BMV 3 isolates was the same in both 'old' and 'young' populations, whereas that of BMV 5 decreased and that of BMV 6 + Ab 12 increased. Despite the contrary shift in the latter two values, a linkage disequilibrium becomes evident in the 'young' population only, towards a higher than expected frequency of samples with the combination BMV 5 plus BMV 6 + Ab 12 ($P < 0.05$). Previous observations had shown that on BMR 6 cultivars that do not possess Ab 12, there was selection against BMV 5. The observation with Triumph suggests therefore that there may be some association between pathogenicity for BMR 5 and Ab 12, though this could not be substantiated from the main survey.

Fungicide insensitivity

Following the widespread introduction and use of triadimefon for control of cereal pathogens in the UK, Dr J T Fletcher and colleagues (ADAS, Newcastle) started a survey for insensitivity to these fungicides in E. graminis f. sp. hordei in treated and untreated fields. Population samples with significantly less sensitivity than normal were found in treated fields. A sub-sample of one of these populations was tested twice in the survey, using detached leaf segments from test seedlings grown from untreated and triadimefon-treated seeds. The tests confirmed the marked insensitivity of the samples compared with control isolates, although the apparent degree of insensitivity appeared to be less than that obtained on whole plants in Newcastle. The reason for this discrepancy may be due either to a decrease in insensitivity during storage of the isolates at the Plant Breeding Institute, or, more likely, to the use of only the first seedling leaves in the Institute tests which increased the effective dose of the fungicide per unit leaf area compared with that in intact seedlings at later growth stages.

Separate analysis of the colony numbers from the leaf tip and base segments revealed an apparently lower degree of insensitivity in the pathogen inoculated on the tip than on the base. This was thought to be due to uneven distribution of the fungicide even in the first leaf with a tendency to accumulate at the distal end.

Insensitivity to these fungicides has also been found in Germany (Mr E Limpert, pers. comm.): approximately 60 per cent of the isolates show this character in areas of northern Germany where the fungicide has been intensively used on winter barley. The practical significance of these observations in the UK and Germany has not yet been resolved.

YELLOW RUST OF BARLEY

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The number of samples received in 1980 was the highest since 1974. The increase in frequency by BYV 2 noted in 1978 has continued in 1980, probably as a result of the widespread cultivation of Mazurka (BYR 2). A number of cultivars produced unexpected resistant reactions to an isolate collected in 1979, and have tentatively been grouped together.

INTRODUCTION

The specific resistances (BYR factors) identified in barley cultivars to date, test cultivars possessing each resistance and the year of first detection of 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

Methods were similar to those described for wheat yellow rust by Priestley (1978).

Seedling tests with 1980 isolates

A total of 134 samples were received by post during 1980. This was higher than any year since 1974 and reflected the relatively high incidence of the disease in 1980. The samples had been collected in a non-random way from Athene (11 samples), Triumph (7), Dragon (7), Goldmarker (7), Sonja (6), Ark Royal (5), Cerise (5), Claret (5), Flare (5), Kym (5), and 31 other cultivars. Isolates were made from 56 samples; 43 failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Berac; the remainder were lost due to growth chamber failure. Virulence tests were carried out on all 56 isolates.

Adult plant tests with 1979 and control isolates

Tests to measure the virulence of P. striiformis isolates on adult spring barley plants were continued in 1980 using the Polythene tunnel method developed for wheat yellow rust (Priestley & Byford, 1978). Details of the isolates used are given in Table 2. Two replicate tussocks of 36 cultivars were sown on 18 March 1980, inoculated on 23 May and 6 June and assessed for percentage leaf area infection on 17 June (GS 71-75), 30 June (GS 85), 10 July (GS 85-91) and 17 July (GS 88-91).

Table 2. Isolates used in adult plant tests

Code	Cultivar	Region*	Site	V Factors
75/37	Mazurka	E	NIAB Cambridge	BYV 0
75/101	Varunda	YL	Boroughbridge	BYV 1,2
79/7	Sonja	W	Barry	BYV 1

* E, East; YL, Yorks and Lancs; W, Wales

VIRULENCE TEST RESULTS

Seedling tests with 1980 isolates

Sampling was not carried out on a random basis and therefore the virulence frequencies for 1972 to 1980 (Table 3) should be interpreted with care. Nevertheless, it seems clear that the increase in frequency of WYV 2 noted in 1978 (Priestley & Byford, 1979) has continued since then. The increase in virulence frequency is almost certainly the result of the popularity of the cultivar Mazurka which possesses BYR 2. Seed sales of this cultivar (expressed as a % of total spring barley seed sales) were negligible before 1973. Sales increased in 1973 (1.9%), 1974 (8.0%) and 1975 (12.5%) reaching a peak in 1976 (14.4%). Since then, sales have slowly declined in 1977 (12.7%), 1978 (9.2%), 1979 (7.6%) and 1980 (4.5%). There seems to have been a lag phase of several years between the increase in area of Mazurka and the general increase in the frequency of

Table 3. Virulence factor frequency (%)

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

Table 4. Results of adult plant tests

R = resistant seedling reaction
For explanation of boxes see text

BYR factor	BYV factor / Isolate / Cultivar	BYV 0 75/37	BYV 1,2 75/101	BYV 1 79/7
BYR 1	Atem	2R	4	2R
	Sundance	0R	2 A	3
	Zephyr	2R	6	6
BYR 2	Varunda	2R*	8 B	1R
	TWZ 340	0R	7	0R
x	FD 0218/490	0	1	1R
	HJ 462/20	3	3	2R
	Porthos	2	4	2R
	Triumph	2	5	3R
	Goldmarker	1	4	3R
	VB 422374/2	2	4	2R
	HJ 460/22	6	6	3R
	Simon	9	10	4R
BYR 0	Cebeco 7722	0	0	0
	HW 56/43	1	1	0
	17421 Co 15	1	2	0
	Athos	1	2	1
	Havila	2	3	0
	Tintern	2	2	2
	Erna	2	5	1
	Dragon	2	5	2
	Georgie	3	4	2
	Antler	4	2	4
	Ark Royal	3	5	3
	Koru	1	6	5
	Egmont	3	7	2
	Claret	2	4	6
	Cerise	3	5	5
	Kym	7	4	6
	Aurea	3	7	8
	VB 412874	4	8	6
	Flare	5	8	7
	W 6702	5	7	9
	Midas	5	8	10
	Keg	7	9	7
	Tyra	5	8	12

* a susceptible reaction was produced in one test in 1980 indicating possible contamination of this isolate with BYV 2.

WYV 2 in the pathogen population. As yet, there has been no decline in the frequency of WYV 2 even though the area sown with Mazurka has recently begun to decrease. This may be the result of a lag phase, or it may be an indication that stabilizing selection is not taking place.

Seedling and Adult plant tests with 1979 and control isolates

The results of the tests are given in Table 4. Disease levels were substantially lower than in previous years but, nevertheless, some tentative conclusions can be drawn from the results. Isolates possessing BYV 1 produced slightly higher levels of infection than other isolates on cultivars Atem, Sundance and Zephyr (Box A). Similarly, isolate 75/101 produced a higher level than other isolates on Varunda (Box B). The seedling test with isolate 79/7 produced unexpected resistant reactions on a number of cultivars. Previous tests have suggested that the resistance of Atem was similar to Sundance and Zephyr but isolate 79/7 demonstrates that Atem has additional resistance to BYR 1 that is absent from the others. The other cultivars that produced resistant reactions to isolate 79/7 have tentatively been placed in group x. It should be emphasized that these groupings are very tentative and require confirmation before firm conclusions are drawn.

The remainder of the cultivars produced susceptible seedling reactions to all three isolates. Despite this, it was noticeable that patterns of infection levels in adult plants in some cultivars were similar to cultivars with specific resistances, for example the pattern of infection level in adult plants for Erna and Dragon were superficially similar to Porthos and Triumph.

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BROWN RUST OF BARLEY

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Seventy one samples of barley brown rust (Puccinia hordei Otth) were received in 1980. Isolates from 45 of the samples were tested on the standard differentials. The widely virulent race 673 octal was identified from 43 isolates and the remaining two were race 273 octal. Virulences for Simon (Pa_3) and Triumph were not detected. The latter cultivar appears to carry gene Pa_9 plus additional undetermined resistance. These results were confirmed by field isolation nursery tests with specific isolates of P.hordei. These, and previously reported results, allow a current evaluation of resistance relationships in cultivars relevant to UK agriculture. Cultivars have therefore been assigned to barley brown rust resistance (BBR) groups and this should enable consideration to be given to brown rust resistance in cultivar diversification schemes and the mixing of cultivars in heterogenous populations.

GLASSHOUSE SEEDLING TESTS

All except one of the 71 samples of barley brown rust received from the 1981 survey were from spring barley cultivars from south east (15 samples) and south west England (55 samples). Isolates of Puccinia hordei Otth were made from 45 of the samples and of the 26 that failed, 24 were from one batch of samples of senesced leaves sent in mid-August. The 45 isolates were tested on the standard set of nine differential cultivars which carry different identified Pa genes for reaction to P. hordei (Jones and Clifford, 1980). In addition, cvs Triumph, Simon and Mirena were included in all tests.

The tests identified two virulence combinations. The most common (43 isolates) was combination octal 673 which overcomes Pa, Pa_2, Pa_4, Pa_5, Pa_6, Pa_8 and Pa_9. The other combination, octal 273, differs in lacking virulence corresponding to Pa_9 carried by CI 1243. This latter resistance, because of phenotypic information and responses to particular pathogen isolates (Clifford and Jones, 1978; Walthur and Lehmann, 1980), was thought to be present in cv Triumph. However, in the tests reported here Triumph was resistant as a seedling to all isolates of races 673 from this year's survey which suggests that Triumph carries an additional resistance factor(s) to Pa_9 in CI 1243. One isolate was partly compatible (reaction

type 2-3) with Triumph and will be tested further in the 1981 isolation nurseries. Simon was resistant to all isolates as was Ribari, which confirms that it carries Pa_3. Mirena gave a mixed reaction to all but a few isolates of 673 which were relatively compatible and this will also be investigated further.

FIELD ISOLATION NURSERY TESTS

Twenty spring cultivars were sown in four replicates in standard isolation nurseries at the Welsh Plant Breeding Station in 1980. Four such nurseries were sown and inoculated with one of the following isolates:

1. BRS-76-12. Standard isolate 677. Pa_3 and Pa_9 virulent.
2. Isolate ex Mirena 1979 survey.
3. BR/F. Standard isolate 273. Pa_3 and Pa_9 avirulent.
4. Isolate ex Simon.

The results, given as a single assessment made on 12 August, 1980 show that (Table 1) there were overall differences between individual nurseries in amount of infection that developed. However, reference to reaction types that are also given facilitates interpretation of the results. The isolate ex Mirena was not specifically compatible with Mirena and was similar to standard isolate BR/F. The isolate from Simon was virulent on Simon as was standard isolate BRS-76-12 confirming that Simon carries Pa_3. BRS-76-12 also appeared to be specifically virulent on Tyra and Armelle even when allowance is made for differences in mean infection levels between nurseries. This confirms previous observations (Parlevliet and Clifford, unpublished).

The seedling and adult plant results obtained with specific isolates of P.hordei from this and previous years' surveys enables cultivars to be placed in barley brown rust resistance (BBR) groupings which will aid in their rational deployment in agriculture. These groupings are given in Table 2 and are a development of groupings reported earlier (Clifford, Jones and Priestley, 1978).

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Table 1. Barley Brown Rust Isolation Nurseries WPBS 1980

Cultivar	Isolate							
	BRS-76-12		ex Mirena		BR/F		ex Simon	
	%	RT	%	RT	%	RT	%	RT
Vada	13.0	1,2,3*	5.8	1,2	5.0	1,2	3.8	1,2,3
Sundance	10.0	1,2,3	5.3	1,2,3	4.8	1,2	4.3	1,2,3
Porthos	10.0	On,1,2,3	4.5	On,1,2	11.3	On,1,2	5.3	On,1,2,3
Tyra	17.5	4	8.7	4.2	11.0	3	5.0	3,2
Midas	36.3	4	26.3	4	33.0	4	17.5	4
Tintern	14.3	3,2	6.3	1,2,3	9.0	On,1,2	8.8	3,2
Armelle	22.5	4	9.5	1,2,3	10.8	3,2	7.3	3,2
Hassan	10.0	1,2	5.8	1,2	6.3	1,2	4.3	2,3
Athos	7.8	1,2,3	5.0	On,1,2	7.5	On,1,2	4.5	1,2,3
Simon	12.5	3,2	2.3	On,1,2	2.3	1,2	7.8	3
Mirena	11.5	1,2,3	8.8	3,2,1	13.0	1,2,3	8.8	3
Triumph	13.0	3,2,1	7.8	1,2	9.0	1,2,3	4.0	On,1,2
Lofa Abed	17.0	4,2	11.8	3,2	15.0	1,2,3	7.3	3,2
Koru	13.5	3,2	5.0	3,2,1	10.3	3,2,1	6.5	3,2
Egmont	22.0	4	9.5	1,2,3	12.8	3,2,1	5.3	3,2
Claret	13.8	4,2	4.0	1,2,3	6.5	1,2,3	4.0	3,2
Daphne	11.5	On,1	5.3	On,1	5.3	On,1	3.5	On,1,2
Corgi	15.8	4,2	8.5	3,2	7.5	3,2	10.8	3,2
Sergeant	12.5	1,2,3	7.5	1,2,3	7.8	1,2,3	3.8	2,3
Regent	8.3	On,1,2	7.0	1,2,3	10.0	1,2,3	8.5	1,2,3
$\bar{x}$	14.5		7.7		9.9		6.6	

* $\bar{x}$ of four reps, 1 score (12/8/80)

% Percent infection

R.T. Standard reaction type. Different reactions on a leaf separated by a comma with majority response on the left

Table 2. Current evaluation of cultivar resistance relationships in the UK barley:brown rust system

Resistance group	Cultivar	Type of resistance	Year virulence detected
BBR 1	Vada Varunda Sundance Georgie Abacus Lofa Abed Koru	Partially expressed[1] (slow rusting) ex Hordeum laevigatum	-
BBR 2	Emir Hassan Aramir Maris Mink Athos Porthos Tintern Regent Daphne	Partially expressed (slow rusting) ex Arabische	-
BBR 3	Armelle Tyra (Egmont)	Partially expressed (slow rusting)	-
BBR 4	Simon	Overall[3] (Gene Pa_3)	1976[2]
BBR 5	Triumph	Overall (Gene Pa_9 + ?)	
BBR ?	Mirena Claret Corgi Carnival		

[1] Clifford (1972)
[2] Clifford & Clothier (1976)
[3] Zadoks (1961)

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RHYNCHOSPORIUM OF BARLEY

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From the 91 samples of barley rhynchosporium received, 50 isolates of Rhynchosporium secalis (Oud.) J.J. Davis were successfully cultured and tested in the glasshouse on seedlings of standard differential cultivars and additional winter and spring cultivars. Certain isolates, classified on this basis as race UK 2, were subsequently found to carry additional virulence for Igri and were designated race UK 5. Barley rhynchosporium resistance (BRR) factors were allocated to type-cultivars and corresponding virulence factors were concomitantly allocated to races UK 1 to 5. Virulence combination RsV 1,2,3 carried by race UK 2 is common and widespread.

INTRODUCTION

The main agricultural interest in Rhynchosporium secalis is currently focussed on disease levels in autumn-sown cultivars and in particular on the effectiveness of resistance in cvs Igri, Athene and Sonja. High levels of infection on Igri had been reported in the previous season and so field sampling and virulence analysis were concentrated on this cultivar.

MATERIALS AND METHODS

A total of 91 samples was received, originating as follows :

(a) Host origin		(b) Geographic origin	
Winter cultivars	64	Wales & western England	74
Spring cultivars	14	Scotland	11
Unnamed grass	1	Northern England	4
Rye	1	Eastern England	2
Unspecified	11		
Total	91	Total	91

Of these, 41 failed to culture including a batch from S.W. England collected at the end of May (the peak of a drought) and a number of spring cultivars sent from the north of Scotland in July. The samples from an un-named grass and from rye failed to infect barley. All of the 50 samples from which R.secalis was successfully isolated were from winter cultivars and of the original winter samples, 18 were from Sonja, 14 from Igri, 11 from Athene, 9 from Maris Otter, 3 from Hoppel, 2 each from Astrix, Video and Gerbel and 1 each from Katy, Marko and Maris Trojan. Particular attention was paid to isolates from Igri and during April 1980

field samples of Igri with unusually high levels of infection were sent in from ADAS pathologists in S.W. England and S.Wales. In addition, a visit to S.Wales on 27 April was arranged by Dr R. Cooke, ADAS, Cardiff, to observe infected fields of Igri and other cultivars and to collect samples. Six samples were obtained from Igri in this way and an additional nine samples came through the normal course of the Survey. Glasshouse seedling tests were carried out on all isolates successfully cultured using standard procedures and differential cultivars as described by Jones and Clifford (1979).

RESULTS

When classified by their reactions on the standard set of differential cultivars, 48 of the 50 isolates were classified as race UK 2 and the remaining two were race UK 3. Of the 14 samples from Igri, three failed to culture, six isolates gave the usual interaction with Igri, and five gave unusually high, or very high, infection levels on this cultivar Determination of 'increased virulence' tends to be a matter of judgement on the part of the observer as changes are quantitative rather than qualitative. However, based on the normal interactions of previously identified virulence carriers (races) with the standard differential cultivars (Table 1), increased virulence can be invoked in certain of the isolates from this year's survey. Specifically, five of the isolates from Igri gave much higher than the normally expected 30% level of infection on Igri and five isolates from cultivars other than Igri also gave high levels of infection on Igri.

Table 1. Typical interactions of known races of Rhynchosporium secalis with standard differential cultivars of barley

	Differential				
Race	Maris Mink	Armelle	Katy	Athene	Igri
UK 1	80*	0	25	0	30
" 2	80	40	25	35	30
" 3	80	0	0	35	30
" 4	80	40	0	35	30

*Percentage infection

The results obtained with representative isolates are given in Table 2, expressed as percentage responses and also reaction types (Ali and Boyd, 1974) Where more than one reaction type was observed on a plant they are separated by a comma with the majority reaction to the left. Two

Table 2. Reactions[+] of selected Igri-virulent and Igri-avirulent isolates of Rhynchosporium secalis from 1980 survey

Isolate Code	Origin	Maris Mink	Armelle	Katy	Athene	Igri	La Mesita	Maris Otter	Maris Trojan	Sonja	Astrix	Mirra	Hoppel	Gerbel	Magnum	Race UK
80/5	Igri	70/4	60/4	50/4	60/4	40/4	0	80/4	40/4,2	15/4,1	50/4	40/4,2	25/4,2	20/4,2	0	5
80/17	Igri	70/4	60/4,1	40/4,2	80/4	50/4	1/1	60/4,2	50/4	25/4,2	5/3,1	50/4	25/4,1	40/4,2	0	5
80/11	Igri	60/4	30/4,1	20/3,1	35/4,2	20/4,1	0	50/4	35/4,1	15/4,1	25/4,1	25/4,1	15/3,1	20/4,1	0	2
80/15	Igri	70/4	50/4	30/4,2	60/4	30/4,2	0	70/4	40/4	20/4,2	40/4,2	40/4,2	25/4,2	25/4,2	2/3	2
80/4	Gerbel	70/4	50/4,2	25/4,1	70/4	50/4,2	0	70/4	50/4,2	25/4,1	-	40/4,2	15/3,1	25/4,1	0	5
80/28	Unknown	80/4	60/4	50/4	70/4	60/4	3/3,2	80/4	70/4	15/4,1	50/4,2	50/4	50/4	30/4,2	0	5

[+]See text for explanation

isolates, 80/11 and 80/15 gave typical race UK 2 reactions but the other four isolates possessed additional virulence on Igri. It is therefore proposed to designate this new combination of virulence as race UK 5. In addition, isolate 80/28 was generally aggressive and also appears to carry specific virulence for Hoppel. Further tests on this isolate and also isolates 80/5 and 80/17 will be carried out in the standard isolation nurseries in the field in the 1981 season.

With the information now in hand it is proposed to allocate cultivars relevant to UK agriculture to resistance factor groups which are given in Table 3.

Table 3. Cultivar resistance factor

Resistance factor symbol		Cultivar	Virulence detected
BRR	0	Maris Mink	Yes
BRR	1	Armelle	Yes
BRR	2	Katy	Yes
BRR	3	Athene	Yes
BRR	4	Igri	Yes
BRR	5	La Mesita	No

Following from this, the various races of R.secalis may be classified according to the virulences that they carry (Table 4) to these specific resistances:

Table 4. Pathogen virulence factors

Race designation	Corresponding virulence factors (BRV)
UK 1	-
UK 2	1,2,3
UK 3	3
UK 4	1,3
UK 5	1,2,3,4

Of particular significance is the finding that virulence combination 1,2,3 (race UK 2) is common and widely distributed. The new combination BRV 1,2,3,4 carried by race UK 5, was detected in Devon and South Wales and the seed-borne nature of the pathogen will no doubt contribute to the wide dissemination of this virulence combination.

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NET BLOTCH OF BARLEY

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Of the 72 samples of Pyrenophora teres Drechs. received, 40 were from infected leaves collected from the field in 1980 and 32 were plate cultures obtained from an A.D.A.S. field survey in 1979. The majority of samples were from winter cultivars from south-central and south-western England. Methods of pathogen culture and plant inoculation were developed and a set of differential cultivars relevant to U.K. barley breeding programmes was assembled. Specific virulence to all of these host resistances was detected, with some occurring at high frequencies in the pathogen population. Virulences occurred in various combinations with some isolates carrying from five to seven. Certain virulences occurred at very low frequencies and the corresponding resistances, namely those in CI5401, CI6311 and CI9820 are currently being exploited in U.K. breeding programmes.

INTRODUCTION

Net blotch of barley, caused by Pyrenophora teres Drechs. has recently become widespread and locally damaging in Britain, especially in the south and west of England on the greatly expanded winter barley acreage. This has brought a response from U.K. barley breeders to incorporate genetic resistance into new cultivars and concomitant with this, there is the need to monitor pathogen variation in relation to such resistance. To this end, preliminary studies of pathogen variation and the identification of host resistance for use in breeding programmes have been carried out at the Welsh Plant Breeding Station (Clifford, Habgood & Jones, 1981). Following this, formal virulence surveys were begun in the 1980 season as part of the U.K. Cereal Pathogen Virulence Surveys.

MATERIALS AND METHODS

Fourty field samples were received during the spring of 1980. The majority were from south-central England and 34 were from winter cultivars. An additional 32 samples were received as plate cultures from the Agricultural Development and Advisory Service, Bristol: these had been isolated during the 1979 season, mainly from winter barleys in the Gloucestershire, Wiltshire and Avon area. Of these 72 isolates, 57 were from winter cultivars, mainly from Sonja (28), Igri (15) Hoppel (5), Athene (4) and Maris Otter (3). Of the remainder, 11 were from unnamed winter cultivars and four were from spring cultivars.

Following experimentation during the winter, a standard procedure for inoculum production and plant inoculation and assessment was developed which overcame most of the difficulties encountered. The procedure is a compromise as the pathogen isolates showed considerable variation for growth and sporulation characteristics in culture and for aggressiveness on plants. Segments of infected leaves from the 40 field samples were cut and surface sterilized by immersing in 90% ethanol for 10 sec. followed by 1% sodium hypochlorite for 90 sec. and then rinsing in sterile distilled water. The segments were than placed in Petri dishes containing lima bean agar (Difco Laboratories, Detroit, Michigan, U.S.A.) which were themselves placed in a near-ultra violet (black) light cabinet set to give an 8h photoperiod at room temperature (18°C approx.). Sub-samples were taken from the edge of colonies 3 - 5 days later where necessary but in most cases pure cultures developed from the leaf segments and further purification was not necessary. The 32 agar cultures received from Bristol were sub-cultured onto lima bean agar and all cultures were subsequently treated in the same way. Spore suspensions for plant inoculation were obtained from approximately 10 day old cultures by flooding the Petri dish with 20 ml of a 0.5% gelatin solution. The agar surface was gently rubbed with a glass rod and the resulting spore and mycelium suspension was filtered through muslin into 200 ml medical flats ready to inoculate plants.

A set of differential cultivars was selected on the basis of preliminary results (Clifford, et al. 1981) which indicated that they carry resistance of value to U.K. breeding programmes. The cultivars were arbitrarily coded from 1 to 12 for convenience and are listed in Table 1.

Table 1. Differential cultivars used for isolate testing

Code No.	W.P.B.S. Accession No.	Cultivar	Type
1	Cb 1613	C.I. 5401	Spring
2	Cb 1615	C.I. 6311	Spring
3	Cb 1619	C.I. 9820	Spring
4	Cb 1593	C.I. 739	Spring
5	Cb 1595	C.I. 1243	Spring
6	Cb 1606	C.I. 4795	Spring
7	Cb 1605	C.I. 4502	Spring
8	Cb 1611	C.I. 4979	Spring
9	Cb 763	Proctor	Spring
10	Cb 3661	Code 65	Winter
11	Cb 3662	C.I. 9518	Winter
12	Cb 3663	Tenn.61-119	Winter

Four pre-germinated grains of each differential cultivar were sown in clumps in 120 mm pots. Six clumps were sown around the periphery of each of two pots which were placed in a sporeproof glasshouse. Natural daylight was supplemented by 400 W Hg vapour lamps to give an 18h photoperiod and the temperature was contolled to a daytime maximum of 22°C and a nighttime minimum of 7°C. When in the 3 - 4 leaf stage the plants were placed in a dew simulation chamber (Clifford, 1973) set at 15°C for 6h prior to inoculation. The spore and mycelium suspension was then sprayed onto the plants in a rotary spray tower and the plants were returned to the dew-chamber for 24h prior to transfer back to the sporeproofed glasshouse. Two disease assessments were carried out approximately 14 and 21 days after inoculation depending on the rate of symptom development, using the reaction type assessment key of Khan and Boyd (1969). The infection classes used are given in Table 2.

Table 2: Reaction-type classes for Pyrenophora teres on barley

Class	Reaction
0	No observable infection.
1	Pin-point brown lesions, no chlorosis.
2	Small dark brown lesions, no chlorosis.
3	Restricted long brown streaks, slight associated chorosis.
4	Brown elongated lesions with net-like cross variations, marked chlorosis.

In addition, note was made of the type of symptoms on the original field sample leaves i.e. netting, spotting or streaking. For the purpose of determining virulence frequencies, reaction classes 0, 1 and 2 were considered to be resistant and classes 3 and 4 as susceptible (avirulent and virulent).

RESULTS

The different siolates of P. teres varied considerably in their cultural characteristics and aggressiveness. Some isolates failed to sporulate on agar, others failed to produce symptoms or produced only limited symptoms on the differential cultivars. The cultures isolated directly from the 1980 leaf samples sporulated better and were more aggressive than the cultures submitted by A.D.A.S. and which were obtained from the field in 1979 and subsequently maintained on potato dextrose agar. This can be seen from Table 3.

Table 3. Percentages of isolates with particular growth characteristics obtained from agar plates (1979) or leaf samples (1980)

Category	Origin	
	Agar Plates (ADAS 1979)	Field leaf samples (1980)
Failed to sporulate	15.6	10
Non-aggressive	37.5	17.5
Mixed responses	0	5.0
Aggressive	46.9	67.5
(Total number	32	40)

Because of these differences between the two groups of isolates and the fact that they represent sampling from two different years, virulence analysis was carried out on them separately.

Agar plate cultures (1979)

From the frequencies of individual virulences corresponding to resistance factors in the 12 differential cultivars given in Table 4 it can be seen that a wide range occurs, from the very high frequencies on differentials 9 (Proctor) and 11 (C.I. 9518), through the low frequencies on numbers 3 (C.I. 9820), 4 (C.I. 739) and 7 (C.I. 4502) to the zero values for 1 (C.I.5401), 2 (C.I. 6311) and 6 (C.I. 4795).

Table 4. Frequencies of virulences corresponding to each differential cultivar (1979 and 1980 isolates)

Differential	Virulence Frequency (%)	
	1979	1980
1	0	4
2	0	4
3	7	11
4	7	0
5	20	11
6	0	18
7	7	18
8	20	37
9	87	81
10	33	26
11	93	96
12	27	55

These virulences occurred in various combinations in the different isolates (Table 5) ranging from the simple common combination of virulences 9 and 11 to the more complex and infrequent 5, 7, 8, 9, 10, 11 or 4, 9, 10, 11, 12.

Table 5. Virulence combinations and their frequencies (1979 isolates)

Virulence combination	Frequency (%)
9	7
9, 11	40
5, 9, 11	7
3; 11, 12	7
9, 10, 11, 12	7
4, 9, 11, 12	7
5, 8, 10, 11	7
8, 9, 10, 11	7
4, 9, 10, 11, 12	7
5, 7, 8, 9, 10, 11	7

Field leaf samples (1980)

The individual virulence frequencies present in the 1980 samples (Table 4) are similar to those sampled from the 1979 population. However, virulences to differentials C.I. 5401 (Code 1), C.I. 6311 (Code 2) and C.I. 4795 (Code 6) were detected whereas virulence to C.I. 739 (Code 4) was not. Overall, virulence to these four resistances, together with C.I. 9820 (Code 3) and C.I. 4502 (Code 7) occurred infrequently. The virulences occurred in various combinations (Table 6).

No relationship was found between the type of field symptoms observed (streaking, netting or spotting), the growth of the cultures in vitro and symptom expression on the differential cultivars. No spotting symptoms were expressed on the fully susceptible differentials Proctor and C.I. 9518. These observations are at variance with Smedegaard-Petersen (1971) who considers that there are two separate forms: P. teres f. teres which causes a net blotch and P. teres f. maculata which causes a spot blotch. He reports that the two forms hybridize and also considers that P. teres f. maculata is the same as P. japonica.

Table 6. Virulence frequencies and their combinations (1980 isolates)

Virulence combination	Frequency (%)
11	4
11, 12	4
9, 11	22
3, 9	4
9, 11, 12	11
8, 11, 12	4
9, 10, 11, 12	7
7, 8, 9, 11	7
2, 8, 10, 11	4
8, 9, 11, 12	4
5, 8, 9, 11, 12	4
7, 8, 9, 11, 12	4
(3), 5, 6, (9), 11	4
2, 5, 9, 11, 12	4
(1), (3), (7), 10, 11, 12	4
6, 8, 9, 10, 11, 12	4
6, 7, 8, 9, 10, 11, 12	7

CONCLUSIONS

The net blotch pathogen, Pyrenophora teres, exists in physiologically specialised forms on barley in Britain. However, the specific virulence factors carried by different isolates of P. teres appear to occur at different frequencies. These virulences correspond to the resistance factors in a set of 12 differential cultivars, none of which are known to be present in barley cultivars currently grown in Britain. It is reasonable to assume therefore that sampling of the pathogen population for these virulences was at random and that the observed frequencies approximate their real values in the field. It may be inferred that certain of these resistances are of more value than others in breeding programmes and in fact those with low corresponding virulence frequencies, namely those carried by C.I. 5401, C.I. 6311 and C.I. 9820 are currently being exploited. It is suggested that the resistances from C.I. 739, C.I. 4795 and C.I. 4502 would also be of value.

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MILDEW OF OATS

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The number of samples received and successfully cultured was greater than in the average year, probably due to the higher incidence of oat mildew in 1980.

The predominant virulences remained the same as in the previous year with OMV 1 + 2 (Race 3), which attacks OMR group 2 cultivars such as Trafalgar, showing 51% frequency; a slight decrease of 11% over the 1979 value. The next most prevalent virulence was OMV 1 + 2 + 3 (Race 5), which produces a susceptible reaction on cultivars of both OMR group 2 and 3 (Pinto, Mostyn etc.) cultivars. This more complex virulence was at a frequency of 41%, a slight increase of 3% over the previous year.

Virulence to Avena barbata seedling resistance was detected in survey samples for the first time. It was found to be already combined with the other known virulences, namely, OMV 1 + 2 and OMV 1 + 2 + 3; this newer virulence is being designated as 4 and the combinations as Races 6 and 7 respectively.

Percentage mildew infection recorded on adult plants of twelve cultivars with known resistances, and grown in four field isolation nurseries, indicated that satisfactory isolation was not possible in a year of high mildew incidence. Therefore, it is proposed to attempt a new method in 1981 of monitoring any adaptation in mildew isolates to the adult plant resistance now present in certain cultivars.

METHODS OF TESTING

Seedling test

A total of 96 samples was received in 1980, a larger number than is usual, probably due to the prevelance of oat mildew during this season. Unfortunately, all those from Eire and several from Scotland failed to culture due to the samples being from plants at late stages of growth. Postal delays were also contributory to these failures. However, 63 samples were successfully cultured and virulences identified. Thirty of these samples were from England (7 locations), twenty two from Wales (11 locations) and eleven from Scotland (1 location). Nine samples were from winter oat and 54 were from spring oat cultivars.

Details of the methods used were identical to those described by Jones and Jones (1980).

Adult plant tests

Twenty cultivars (Table 4) which included the four winter and seven spring oat cultivars on the 1980 NIAB Recommended List, also the cultivar Mostyn and eight WPBS breeders' lines, were sown in four separated isolation nurseries at the Welsh Plant Breeding Station. Sowing arrangement and layout were as described by Jones and Jones (1980) with four replications of the twenty cultivars in each nursery. The same four mildew isolates used in 1979 with known virulences (Table 4) were again used and introduced into the nurseries when plant growth was at about the four leaf stage.

The percentage of the leaf area covered with mildew in each clump of the test plants was recorded on three successive dates during the season, namely, 18 - 20 June (G.S. 8-9), 3 - 9 July (G.S. 10.2) and 23 - 25 July (G.S. 10.5.3) the last score being for the flag leaf only.

RESULTS AND DISCUSSION

Seedling tests

The resistance grouping of certain named cultivars, which have been placed on the NIAB Recommended List or have appeared in National List trials since those given in the UKVS Annual Report for 1978 have been determined and are presented in Table 1.

Table 1. Resistance grouping of named new cultivars

OMR group	Differential cultivar	Cultivars
0	Milford	Fyne, Perona, Saracen, Portmore, Dula
1	Manod	
2	Cc 4146	Blyth, Orlando, Siluria, Colt
3	9065 Cn 6/3/74	Pinto, Lucy, Menai
4	Cc 6490	

Details of the host cultivars and location from which leaf samples were received, and mildew cultures established, are given in Table 2 together with the virulences identified.

The frequency of occurrence of the various virulences in 1980 compared with the previous two years is presented in Table 3. The same general trend shown in previous years was again evident in that OMV 1 + 2 (Race 3) virulence (attacking such cultivars as Trafalgar and Maris Tabard) was predominant with 51% frequency, while the more complex OMV 1 + 2 + 3

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

Location	Virulences	Cultivars
ENGLAND		
Harper Adams College Newport, Salop	1+2	Peniarth
	1+2+3	Panema
	1+2+4	Pennal
Leeds, West Yorks.	1+2+3	Trafalgar
Slate Hall, Cambridge	1+2	Leanda, Maris Tabard
Trumpington, Cambridge	1+2	Maris Tabard, Unknown, Leanda
Morley, Norfolk	1+2	Fyne, Maris Oberon, Leanda, Siluria, Maris Tabard
	1+2+3	Trafalgar, Orlando, Blyth
Wye, Kent	1+2	Peniarth
Seale Hayne, Devon	1+2	Siluria, Maris Oberon, Trafalgar, Saladin, Orlando, Saracen, Leanda
	1+2+3	Maris Tabard, Fyne, Lucy, Pinto
	1+2+4	Blyth
WALES		
Trawsgoed, Dyfed	1+2	Maris Tabard
	1+2+3	Leanda, Pinto, Maris Oberon, Orlando
Lampeter, Dyfed	1+2	Trafalgar
Frongoch, Aberystwyth	1+2+3	Trafalgar, Maris Tabard, Leanda
WPBS, Aberystwyth,Dyfed	1+3	Peniarth, Panema
	1+2+3	Pennal, Pontiff, 2261-80, Trafalgar
	1+2+3+4	Orlando
Three locations in Powys	1+2+3	Mostyn, Mostyn, Mostyn
Three locations in Clwyd	1+2	Trafalgar, Mostyn?
	1+2+3	Mostyn
SCOTLAND		
Legerwood Borders Berwick	1+2	Blyth, Trafalgar, Perona, Orlando, Maris Tabard, Lucy Saladin, Siluria, Leanda
	1+2+3	Pinto, Fyne

virulence combination was the next most frequent (41%). The latter produces a susceptible reaction on both group 2 (Trafalgar etc.) and group 3 cultivars (Panema, Pinto, Mostyn etc.).

Table 3. Virulence group frequencies identified from samples received in 1980 compared with previous two years

Virulence group (Race)	No. of isolates in 1980	Frequency (% total) 1980	1979	1978
OMV 1 (2)	0	0	0	3
OMV 1 + 2 (3)	32	51	62	42
OMV 1 + 3 (4)	2	3	0	3
OMV 1 + 2 + 3 (5)	26	41	38	52
OMV 1 + 2 + 4 (6)	2	3	0	0
OMV 1 + 2 + 3 + 4 (7)	1	2	0	0

As in the previous year none of the cultures was of the simple virulence OMV 1 (Race 2), the cultivars with the corresponding resistance factors (OMR group 1) such as Peniarth being colonized by the more complex virulences (Race 3 and 5).

There were two samples identified as OMV 1 + 3 (Race 4) attacking Panema, Mostyn etc. while in 1979 none was detected. As more cultivars with the corresponding resistance (OMR group 3) such as Pinto and Panema are grown, there could be an increase in this virulence combination, but probably the more complex virulence OMV 1 + 2 + 3 (Race 5) will again become the most frequent, being able to attack cultivars in resistance group 1, 2 or 3.

Two new virulence combinations were detected for the first time in this year's survey. Virulence to the Avena barbata resistance (Aung, Thomas and Jones, 1977) is common to both of these and it is proposed to designate it as OMV 4 (Table 3). It appears to be already combined with other virulences, two samples indicating combination with OMV 1 + 2. These had been collected from the cultivars Pennal and Blyth grown at Newport, Salop and Seale Hayne, Devon respectively. One sample from Orlando from WPBS showed virulence to all the differential varieties used in these tests and is, therefore, the most complex oat mildew virulence so far encountered and is designated OMV 1 + 2 + 3 + 4. The above three cultivars on which mildew with OMV 4 was detected do not carry the A.barbata resistance factor. It is noted that on the A.barbata translocation line

Cc 6490, which was used as a differential in these tests, only 1% of the seedling leaf area was infected, and with a reaction type 3. On further multiplication and testing, however, it proved completely compatible on the A.barbata gene carrier.

Adult plant tests

The results of these tests for the twelve commercial varieties are given in Table 4 for the three dates of recordings together with their arithmetic mean. In 1979 when the level of mildew was extremely low in the area this method of testing provided satisfactory results in that the isolate introduced into a particular nursery remained almost uncontaminated up to the end of the testing season. However, in 1980 with generally much higher incidence of mildew, the introduced mildew isolate in a particular isolation nursery was soon swamped by extraneous mildew from the surrounding area. Even at the first recording on 19 June in the nursery with OMV 1 (Race 2), the OMR group 2 and especially group 3 cultivars, which carry genes with specific resistance to the virulence factors of this race, showed almost as high levels of mildew as cultivars in groups 0 and 1, which lack corresponding genes for resistance. By the second and especially the third recording, the OMR group 2 cultivars were even more extensively infected than the group 0 cultivars including Leanda, indicating severe contamination.

Again in the nursery inoculated with OMV 1 + 2 (Race 3) the cultivars Panema and Mostyn, which in 1979 showed only 1-2% mildew infection due to their specific seedling resistance gene, in 1980 became relatively heavily infected early in the season due undoubtedly to infection by mildew with corresponding virulence from the surrounding area.

The effectiveness of the adult plant resistance of Saladin and some of the winter oat cultivars such as Peniarth to all four isolates used in this experiment contrasts markedly with the very often increasing susceptibility of cultivars in OMR group 2 as the season progressed.

Due to the unreliability in most years, of this method of testing for any adaptation in mildew isolates to genetic resistance expressed as the adult plant stage of growth, it is proposed to attempt another method in 1981. It consists of using detached leaf segments from adult plants grown in mildew free conditions, and the segments placed on benzimidazole/agar in polystyrene compartmented boxes. Field crops or plots of cultivars reputed to have adult plant resistance would be monitored by exposing in them

Table 4. Percentage leaf area covered with mildew of 12 oat cultivars grown in four isolation nurseries in the field and inoculated with four different mildew isolates

Cultivar	OMR group	OMV 1 (Race 2)				OMV 1 + 2 (Race 3)				OMV 1 + 3 (Race 4)				OMV 1 + 2 + 3 (Race 5)			
		19/6	9/7	23/7	Mean	20/6	3/7	23/7	Mean	19/6	9/7	24/7	Mean	18/6	8/7	25/7	Mean
Leanda	0	22	29	46	32	30	39	45	38	31	16	29	25	48	30	29	35
Saladin	0	18	7	18	14	25	29	12	22	26	10	13	16	42	21	10	24
Fyne	0	21	18	34	24	26	31	26	28	28	11	19	19	48	25	14	29
Peniarth	1	18	14	15	15	26	29	21	25	26	8	14	16	31	21	14	22
Pennal	1	20	20	25	22	26	34	18	26	38	14	21	24	41	18	22	27
Maris Osprey	1	10	11	23	15	21	28	22	24	24	11	23	20	39	20	20	26
Maris Oberon	2	16	26	50	31	31	41	62	45	26	12	23	20	45	36	41	41
Maris Tabard	2	19	30	50	33	25	41	52	40	28	14	29	24	35	34	41	37
Trafalgar	2	18	26	54	32	31	38	46	38	32	18	41	31	50	35	40	42
Blyth	2	21	22	38	27	32	39	52	41	38	14	29	27	50	39	46	45
Panema	3	12	12	19	14	15	24	18	19	29	11	19	19	35	22	19	25
Mostyn	3	15	22	35	24	16	21	32	23	32	21	39	31	50	31	42	41

mildew free segments of the particular crop cultivar together with a restricted number of control cultivars. If any adaptation is detected, the isolate would be further tested in the laboratory against a range of resistance carriers under controlled conditions.

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OAT CROWN RUST

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Only 5 samples were received and from these the common race 251 was identified in all cases. In one sample from winter oats race 251 was mixed with the more widely virulent race 265.

Code	Cultivar	Location	Race
CRS-80-1	Saracen	Devon	251
2	Trafalgar	Cornwall	251
3	Astor	Dyfed	FTC
4	Winter oats	WPBS	251 + 265
5	*Avena strigosa*	Dyfed	251

CULTIVAR DIVERSIFICATION SCHEMES FOR WINTER WHEAT AND SPRING BARLEY, 1981

Cultivar 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 1981 versions which update those in the last Annual Report.

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

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

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CULTIVAR DIVERSIFICATION SCHEME TO REDUCE SPREAD OF YELLOW RUST AND MILDEW IN WINTER WHEAT 1981

Severe infections may result if yellow rust or mildew spreads from an adjacent winter wheat crop into a cultivar with a low level of resistance. This risk can be reduced by choosing cultivars with high levels of resistance. Further benefit can be obtained by sowing adjacent fields with cultivars chosen from different diversification groups as this reduces the spread of disease from one to the other. Similarly, cultivars 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 cultivars are given below.

DG 1B
Avalon
Bounty
Mardler
Sentry

DG 1D
Baron

DG 1E
Aquila
Flanders

DG 1F
Abele
Bouquet
Prince
Rapier

DG 2A
Copain

DG 2B
Hustler
Maris Huntsman
Sportsman
Virtue

DG 3A
Norman

DG 3B
Kinsman

DG 4C
Armada

DG 6B
Brigand

DG 6F
Hobbit
Kador

DG 7D
Stuart

Choosing cultivars to grow together

1) Decide upon first-choice cultivar 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 cultivars are not all susceptible to another disease.

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

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

CULTIVAR DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN SPRING BARLEY 1981

Severe infections may result if mildew spreads from an adjacent barley crop into a cultivar with a low level of resistance. This risk can be reduced by choosing cultivars with high levels of resistance. Further benefit can be obtained by sowing adjacent fields with cultivars chosen from different diversification groups as this reduces the spread of disease from one to the other. Similarly, cultivars 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 cultivars are given below.

DG 1
Atem

DG 2
Midas

DG 3
Aurea
Cerise
Flare
Georgie
Koru
Kym
Lofa Abed
Sundance
Varunda

DG 4
Dragon
Goldmarker
Goldspear

DG 5
Aramir
Athos
Erna
Hassan
Maris Mink
Piccolo
Porthos
Tintern

DG 6
Ark Royal
Keg
Mazurka
Triumph

DG 7
Antler
Tyra

DG 8
Simon

DG 9
Claret
Dram

DG 10
Egmont

Choosing cultivars to grow together

1) Decide upon first-choice cultivar 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 cultivars 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 8	DG 9	DG 10
DG 1	+	+	+	+	+	+	+	+	+	+
DG 2	+	m	+	m	+	+	+	+	+	+
DG 3	+	+	m	m	+	+	+	+	m	m
DG 4	+	m	m	m	+	+	+	+	+	+
DG 5	+	+	+	+	m	+	+	+	+	m
DG 6	+	+	+	+	+	m	+	m	m	+
DG 7	+	+	+	+	+	+	m	+	+	+
DG 8	+	+	+	+	+	m	+	m	+	+
DG 9	+	+	m	+	+	m	+	+	m	+
DG 10	+	+	m	+	m	+	+	+	+	m

\+ = good combination; low risk of spread of mildew.
m = risk of spread of mildew.

Winter barley cultivars

Susceptible winter barley cultivars may act as a source of mildew infection so do not grow susceptible spring barley cultivars near them.