U.K. CEREAL PATHOGEN VIRULENCE SURVEY

1977 Annual Report

U.K. CEREAL PATHOGEN VIRULENCE SURVEY

Chairman: Dr G D H Bell CBE FRS

Secretary: Dr R H Priestley, National Institute of Agricultural Botany,
Huntingdon Road, Cambridge CB3 OLE
Tel: Cambridge (0223) 76381

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MEMBERS OF THE U.K. CEREAL PATHOGEN VIRULENCE SURVEY COMMITTEE, 1977 - 78

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Mrs S E Wright	Plant Breeding Institute, Cambridge

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The yellow rust of wheat paper includes an appendix giving the results of the U.K. and Eire section of the International Survey of Factors of Virulence of *Puccinia striiformis*.

RESULTS

The U.K. 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 of wheat yellow rust and barley mildew tests 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 & 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 diversification schemes, modified to meet regional requierments, 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'.

FUTURE DEVELOPMENTS

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 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.

YELLOW RUST OF WHEAT

R. H. Priestley & P. Byford

National Institute of Agricultural Botany, Cambridge

Virulence for Chinese 166 (R 1), Heine VII (R 2) and Vilmorin 23 (R 3) was found frequently illustrating the relative ineffectiveness of these resistances against the U.K. population of *Puccinia striiformis*. A further isolate was found possessing virulence for Compair (R 8). This virulence was first detected in the U.K. in 1976. Virulence for Clement (R 9) was found for the first time in Eire. Tests have indicated a further slight increase in virulence for Maris Huntsman (R 2,3,13). The increased virulence for Hobbit and Score (R 2,3,4,14) reported in the 1976 Annual Report has been confirmed.

SPECIFIC RESISTANCE FACTORS

Table 1 shows the specific resistance (R) factors identified to date in wheat cultivars, the resistance genes where known, the type of resistance, a test cultivar possessing each resistance and the year of first detection of virulence (V) in the U.K. population of *Puccinia striiformis*.

VIRULENCE TESTS

Seedling tests with 1977 isolates

A total of 39 disease samples was received by post in 1977. These had been collected in a non-random way from Maris Huntsman (6 samples), Hobbit (4), Maris Templar (2), Hustler (2), Cebeco 186 (2) and 19 other cultivars. Isolates were made from 36 samples; the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Sappo.

Virulence compatible with the overall resistances R 1 - R 10 were identified using test seedlings in the 36 isolates. Ten isolates were found to be mixtures of different virulence combinations and have been excluded from virulence frequency calculations.

Adult plant tests with 1976 and control isolates

Race nurseries were sown within Polythene tunnels 5.2m long, 4.3m wide and 2.2m high. Each tunnel was provided with overhead irrigation. The

Table 1. Wheat yellow rust specific resistance factors

R factor	Gene	Type*	Test cultivar	V detected
R 1	Yr 1	overall	Chinese 166	1957
R 2	Yr 2	overall	Heine VII	1955
R 3	-	overall	Vilmorin 23	1932
R 4	Yr 3b + 4b	overall	Hybrid 46	1965
R 5	Yr 5	overall	*T. spelta album*	-
R 6	-	overall	Heine Kolben	1958
R 7	Yr 7	overall	Lee	1971
R 8	Yr 8	overall	Compair	1976
R 9	-	overall	Riebesel 47/51	1974
R 10	-	overall	Moro	-
R 11	-	adult plant	Joss Cambier	1971
R 12	-	adult plant	Mega	1969
R 13	-	adult plant	Maris Huntsman	1974
R 14	-	adult plant	Hobbit	1972

* sensu Zadoks (1961). Overall resistance is effective at all growth stages, adult plant resistance is ineffective at seedling growth stages.

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temperature within a tunnel could be controlled to with 5°C of ambient by removing Polythene panels to increase ventilation. The tunnels provided a humid atmosphere that promoted rapid disease development and also minimised cross contamination between isolates in adjacent nurseries. Cultivars were sown as 230mm diameter tussocks with 230mm between tussocks. Two replicate tussocks of each cultivar were sown in a 6 x 12 arrangement using a randomization balanced in two directions. The tussocks were sown on 16 November, inoculated with a spore-talc mixture on 28 February and 21 March and assessed for percentage leaf area infection using the International Scale on 26 April (GS31), 10 May (37-39), 24 May (45-58) and 8 June (60-71).

Virulences compatible with both overall and adult plant resistances were identified in 20 isolates and an isolate mixture using the above technique. The isolates comprised 8 controls of known virulence from previous years, 9 collected in 1976 from sites with a greater than expected disease level, and 3 from various inoculated plots (Table 2). The isolate mixture comprised equal proportions of 32 other isolates collected in 1976.

Table 2. Isolates used in adult plant tests

Isolate code	Cultivar	Region	Site
Control isolates			
67/336	Joss Cambier	Sc	East Lothian
69/163	Maris Beacon	E	Near Cambridge
71/26	Joss Cambier	SW	Ashbury
71/368	Joss Cambier	Sc	East Lothian
71/493	Capta	Sc	Duns
72/415	Maris Ranger	Sc	East Lothian
74/62	Maris Huntsman	YL	Garton-on-the-Wolds
75/109	Kinsman	WM	Harper Adams
1976 isolates			
76/7	Maris Huntsman	YL	Croft
76/8	Flinor	YL	Oxen-le-fields
76/37	Hawk	N	Buston Barns
76/47	T. spelta saharense	Ei	Leixlip
76/63	Maris Huntsman	N	Buston Barns
76/66	Score	N	Shoreswood
76/67	Sportsman	Sc	Berwickshire
76/71	Grenade	Sc	Mains of Ravensby
76/73	Sportsman	Sc	Montrose
Other isolates			
PBI75/27	plot of Hobbit inoculated with WYR72/23 at PBI		
75/A1	tussock of Clement inoculated with 74/62 at NIAB		
76/A8	tussock of Sportsman inoculated with 74/62 at NIAB		

Two tunnels were inoculated with isolate 74/62 to investigate within-isolate variation. Different randomizations were used in the two tunnels (74/62A and 74/62B).

CHANGES IN VIRULENCE

The results of the adult plant tests are given in Table 3. Isolates 67/336 and 69/163 had become contaminated during spore multiplication with other virulences and have been excluded.

Table 3. Results of adult plant tests

Values are mean percent leaf area infection (2 replicate tussocks, 4 dates).
Underlined values have significantly (P = 0.05) positive two factor residuals indicating large positive interaction between cultivar and isolate.

Boxes indicate compatibility expected from identified R and V factors.

Data for isolates 67/336 and 69/163 omitted.

R factors	Test cv	R 6	R 6	R 7	R 9	R 11	R 11	R 13	R 13	R 13	R 13	R 14	R 14	R x,y	R x,y	R x,y	R x,y	R x	R ?	R 0	Mixture of other 1976 isolates	Maximum % leaf area infection	Diversification Group
	V factors	V 1,2,3,6,x	V 2,3,4,6	V 1,2,3,7	V 2,3,4,9	V 2,3,4,11 ?	V 1,2,3,11 ?	V 1,2,3,13	V 1,2,3,13	V 1,2,3	V 1,2,3,13,x,y	V 2,3,4,14 PBI	V 1,2,3,13	V 1,2,3,13	V 1,2,3,13,x,y	V 1,2,3,13	V 1,2,3,13	V 1,2,3,13	V 1,2,3,13	V 2,3,4,9			
	Isol no	72/415	75/109	71/493	75/A1	71/26	71/368	74/62A	74/62B	76/7	76/63	75/27	76/66	76/67	76/71	76/73	76/A8	76/37	76/8	76/47			
R 0	Michigan Amber	28	33	31	33	31	40	30	37	33	27	31	25	33	29	34	25	26	31	41	43	43	-
R 6	Maris Ranger	20	2	1	0	0	0	3	4	1	1	0	1	0	0	1	0	7	0	4	9	20	3
	Maris Freeman	17	2	1	1	0	0	3	4	0	1	0	0	0	1	0	0	3	0	3	7	17	3
	Kinsman	16	13	3	2	1	1	3	8	0	2	0	2	0	1	1	0	4	2	3	13	16	3
R 1,2,3	Maris Templar	22	0	22	6	9	19	13	16	22	28	4	17	20	26	14	18	17	19	10	28	28	-
R 1,2,6	Rothwell Perdix	24	0	12	7	6	13	9	13	15	18	3	17	8	20	10	11	15	9	12	18	24	-
R 2,3,4	Maris Beacon	2	17	3	16	12	11	13	6	0	1	32	4	6	0	24	0	0	0	19	24	32	-
R 2,3,11	Joss Cambier	43	6	21	17	17	31	19	14	33	33	31	21	36	33	21	19	36	22	34	36	43	-
R 1,2,3,7	Tommy	7	0	37	0	9	13	0	1	1	2	0	0	1	1	0	0	5	0	0	2	37	-
R 1?,2,3,13	Maris Huntsman	15	8	12	7	9	10	15	12	13	26	7	22	15	26	13	16	16	21	11	20	26	2
	Maris Nimrod	20	15	15	7	12	17	20	22	13	26	14	22	20	34	24	23	28	31	16	24	34	2
	Hustler	7	0	5	3	4	7	8	13	17	25	3	19	22	24	13	16	14	21	10	33	33	2
R 2,3,4,9	Clement	1	0	1	26	0	1	0	0	0	1	4	0	0	0	0	0	0	0	47	31	47	7
R 2,3,4,12	Mega	7	0	6	4	2	2	2	4	3	5	3	4	1	4	7	2	2	3	4	5	7	4
R 2,3,4,14	Hobbit	6	0	5	0	3	11	1	3	4	7	28	4	4	6	1	1	2	1	3	6	28	6
	Score	12	0	8	2	4	16	1	4	7	6	31	1	4	10	2	0	2	0	6	9	31	6
	Maris Bilbo	21	14	15	13	10	13	10	10	17	13	41	14	22	18	10	18	6	11	13	17	41	6
	Bouquet	8	0	8	2	1	5	3	4	5	9	11	5	4	7	3	2	3	4	2	7	11	1
R x,y	Sportsman*	2	0	4	0	6	5	6	7	13	13	1	11	6	14	6	3	8	9	7	17	17	2
	Grenade*	6	0	4	4	3	3	4	5	8	12	1	7	7	13	4	7	8	5	3	15	15	2
	Mardler	7	0	4	1	4	4	4	8	5	15	0	11	8	13	2	6	6	4	3	13	15	1
R x	Cappelle-Desprez	22	1	11	2	6	14	9	9	9	18	6	13	12	18	7	6	12	5	8	22	22	5
	Champlein	20	2	13	7	4	15	8	9	10	20	6	10	13	23	11	13	10	10	4	18	23	5
	Hawk	21	1	12	13	8	16	11	10	11	20	1	14	12	27	12	14	12	10	6	13	27	2
	Waggoner	13	8	11	5	12	7	6	7	8	15	11	8	10	19	5	7	6	7	8	17	19	1
	Maris Widgeon	13	2	7	3	5	7	6	9	6	17	6	11	6	19	4	9	7	9	5	15	19	1
	Fleurus	18	7	10	4	10	8	4	9	3	13	12	8	7	16	4	12	5	6	8	14	18	1
	Flanders	14	0	8	0	4	7	3	5	4	9	3	5	3	7	4	3	4	2	1	8	14	1
	Kador	14	2	6	3	2	7	3	6	7	10	12	5	10	12	2	8	9	4	3	9	14	1
	Maris Fundin	13	4	5	1	5	3	5	8	7	12	2	6	3	12	3	1	2	2	3	10	13	1
R ?	Atou	2	0	2	0	0	1	0	1	1	1	0	1	0	1	0	0	0	0	0	2	2	1
	Aquila	1	0	1	0	1	0	1	1	0	1	1	0	0	1	0	0	0	0	0	2	2	1
	Armada	0	0	0	1	0	0	0	0	0	0	0	0	0	0	5	0	0	0	1	6	6	1
	Flinor	3	0	4	1	1	1	1	3	0	3	0	3	1	3	0	4	1	2	0	5	5	1
	Val	0	0	2	0	0	0	1	2	0	3	0	0	0	2	0	0	0	0	0	4	4	1
	Valmy	4	0	4	0	1	1	0	4	1	2	2	1	0	2	0	0	0	0	1	1	4	1
L.S.D. (P = 0.05)		6	4	6	5	4	5	4	4	6	5	4	4	6	6	5	4	6	5	5	7		

* flag leaf more susceptible than lower adult plant leaves

wide range of isolates has shown that a number of isolates collected since 1971 produced higher infection levels than those collected in 1971 and classified as possessing V 11 (Table 3).

Mega virulence (V 2,3,4,12)

No isolates were identified with virulence for the adult plant resistance R 12 possessed by Mega. Previous tests have shown that isolates virulent on Mega are also virulent on Pride (Priestley & Byford, 1976).

Maris Huntsman virulence (V 1?,2,3,13)

R 13 is a very important resistance as it protects the cultivars in group DG 2 in the yellow rust diversification scheme. The tests indicate that Hustler possesses a similar type of adult plant resistance to Maris Huntsman and Maris Nimrod.

A number of isolates (76/63, 76/66, 76/71 and 76/8) produced higher infection levels on Maris Huntsman that the control 'Maris Huntsman virulent' isolate 74/62. This suggests there has been a further slight increase in virulence for Maris Huntsman additional to that previously reported (Priestley & Byford, 1976). The four isolates also produced higher infection levels on Maris Nimrod and Hustler. The mixture of isolates produced a higher infection level than any individual isolate on Hustler, indicating that isolates with further levels of increased virulence were present in the isolate mixture.

Many of the isolates collected in 1976 and previously from cultivars possessing R 13 have possessed V 1. Seedling tests carried out by Dr Johnson at the Plant Breeding Institute, Cambridge have shown that Maris Huntsman does not possess R 1, and thus V 1 is not necessary for infecting seedlings of this cultivar. However, many of the isolates collected over a period of years from Maris Huntsman and other cultivars possessing R 13 have possessed V 1. This suggests that V 1 and V 13 are linked in P. striiformis in some manner. Alternatively, R 1 may be possessed by Maris Huntsman but not expressed at the seedling stage. This seems less likely because there is no evidence for R 1 in the pedigree of Maris Huntsman (R.Johnson, personal communication).

Hobbit virulence (V 2,3,4,14)

R 14 is an important resistance protecting the cultivars in group DG 6 in the yellow rust diversification scheme. The adult plant tests have confirmed previous observations that isolate PBI75/27 is virulent on Hobbit, Score and to a lesser extent Bouquet (Priestley & Byford, 1977). None of the 1976 isolates nor the isolate mixture possessed virulence for these cultivars indicating that V 14 is still rare in the U.K. population of *P. striiformis*.

V x and V x,y

The adult plant tests indicate the presence of two other specific resistances provisionally numbered R x and R y. R x is apparently possessed by a number of cultivars including Cappelle-Desprez, with R x,y possessed by Sportsman, Grenade and Mardler. Previous tests have shown that the resistance of Sportsman and Grenade is expressed less effectively in the flag leaf than in the lower adult plant leaves (Priestley & Byford, 1977), and this may be a characteristic of R y. Sportsman, Grenade and Mardler probably also possess R 1,3,13. Tests at the Plant Breeding Institute, Cambridge have shown that R 2 is present in Mardler but absent from Sportsman (R. Johnson, personal communication).

Virulence for other cultivars

No increased virulence was found for Atou, Aquila, Val or Valmy. The isolate mixture produced a slightly higher infection level than any individual isolate on Armada and Flinor. This may indicate that increased virulence for these cultivars was present in the isolate mixture.

RECLASSIFICATION OF RACES

Races named according to the World and European differential cultivars are reclassified into the following virulence combinations using the resistance factors R 1 - R 10 given in Table 1. 41 E 136 = V 1,2,3; 43 E 138 = V 1,2,3,7; 45 E 140 = V 1,2,3,6; 37 E 132 = V 1,2,6; 104 E 137 = V 2,3,4; 108 E 141 and 108 E 173 = V 2,3,4,6. Virulence for Joss Cambier (R 11), Mega (R 12), Maris Huntsman (R 13) and Hobbit (R 14) cannot be differentiated using the World and European system.

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APPENDIX

Identification of isolates from the U.K. and Eire section of the International Survey of Factors of Virulence of *Puccinia striiformis*

The following isolates have been identified:

Isolate	Cultivar	V factors	W & E race number
77/14*	Compair	V 2,3,4,6,8	?
77/15*	Winnetou	V 2,3,4 + V 2,3,4,9	104 E 137 + ?
77/16*	Orca	V 2,3,4,6	108 E 141 or 108 E 173
77/28**	Caribo	V 1,2,3,7	43 E 138
77/29**	Lee	V 1,2,3,7	43 E 138
77/30**	Lely	V 1,2,3,(7)	?

* collected from Howsham, Lincolnshire

** collected from North Coates, Lincolnshire

YELLOW RUST OF BARLEY

R. H. Priestley & P. Byford
National Institute of Agricultural Botany, Cambridge

Virulence for Astrix (R 1) and Sultan (R 5) was frequently found in 1977 indicating the relative ineffectiveness of these resistances against the present U.K. population of *Puccinia striiformis*. The frequency of virulence for Bigo (R 2) has remained low since it was first detected in the U.K. in 1975. Adult plant tests have shown that the differential effect of R 3 (in Varunda) and R 4 (in Mazurka) is expressed less clearly in adult plants than seedlings. Resistance to *P. striiformis* in wheat and barley cultivars is usually expressed more effectively in adult plants than seedlings.

SPECIFIC RESISTANCE FACTORS

Table 1 shows the specific resistance (R) factors identified to date in barley cultivars, a test cultivar possessing each resistance and the year of first detection of virulence (V) in the U.K. population of *Puccinia striiformis*.

VIRULENCE TESTS

Seedling tests with 1977 isolates

A total of 36 disease samples was received by post in 1977. These had been collected in a non-random way from Sonja (3 samples), Athene (2), Firecrest (2), Albion (2), Jupiter (2), W 6495 (2), Vanja (2), Magnum (2) and 19 other cultivars. Isolates were made from 27 samples; the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Berac.

Virulence compatible with resistances R 1 - R 5 were identified in the 27 isolates using test seedlings.

Adult plant tests with pre-1977 isolates

Tests to measure the virulence of isolates of *P. striiformis* on adult barley plants were carried out for the first time. The technique of growing race nurseries within Polythene tunnels was used (Priestley & Byford, 1978). The tussocks were sown on 17 March, inoculated with a spore-talc mixture on 27 April and assessed for percentage leaf area infection using the International Scale on 26 May (GS 45-50), 31 May (50-58), 9 June (58-60) and 16 June (68).

Table 1. Barley yellow rust specific resistance factors

R factor	Test cultivar	V detected
R 1	Astrix	1960 or earlier
R 2	Bigo	1975
R 3	Varunda	1972
R 4	Mazurka	1974
R 5	Sultan	1967 or earlier

Table 2. Isolates used in adult plant tests

Isolate code	Cultivar	Region	Site
'23' ex PBI61/31	-	E	PBI, Cambridge
'24' ex PBI60/7	-	E	PBI, Cambridge
72/32	Julia	N	-
74/33	Malta	N	Morpeth
74/194	Sundance	N	Cockle Park
75/37	Mazurka	E	NIAB, Cambridge
75/101	Varunda	YL	Boroughbridge
76/20	Ark Royal	YL	Leeming Bar

Eight isolates were selected to include the widest range of variation in virulence noted in previous seedling tests (Table 2).

CHANGES IN VIRULENCE

The results of the adult plant tests are given in Table 3. The cultivars shown to possess R 1 - R 5 have been grouped on the basis of seedling test results. The V factors possessed by each isolate are also based on seedling test results. The boxes indicate incompatibility expected from these R and V factors. The values in the Table are mean percent leaf area infection from adult plant tests. Values within boxes should therefore be relatively small compared with those produced by other isolates on that cultivar. Deviations from this indicate the presence of other resistances and virulences hitherto undetected, or that resistances previously identified in seedling tests may be less or more effectively expressed in adult plant tests. The underlined values have significantly (P = 0.05) negative two-factor residuals indicating a negative interaction between cultivar and isolate. These may be regarded

Table 3. Results of adult plant tests

Values are mean percent leaf area infection (2 replicate tussocks, 4 dates).
Underlined values have significantly (P = 0.05) negative two factor residuals indicating a large negative interaction between cultivar and isolate.
Boxes indicate incompatibility expected from identified R and V factors.

R factors	Test cv / V factors	V 5	V 5	V 1,5	V 1,5	V 1,3,5	V 1,4,5	V 1,3,4,5	V 1,2,3,4,5	Mean	Mildew R factors
	Isol no	75/37	'23'	'24'	76/20	74/33	72/32	75/194	75/101		
R 1	Julia	13	33	37	34	41	44	43	38		R 2
	Zephyr	14	35	39	39	41	38	39	39		R 2
	Abacus	15	33	31	34	48	47	42	46		R 2,4
	Sundance	8	19	15	20	40	24	26	37		R 2,4
R 3	Varunda	18	34	15	11	16	22	16	28		R 4
R 4	Mazurka	35	31	38	31	37	48	36	44		R 2,6
R 5	Sultan	39	46	42	34	36	33	33	33	39.2	R 5
R ?	Hassan	32	44	35	31	37	33	29	18	32.4	R 5
	Maris Mink	35	42	33	24	24	31	30	17	28.6	R 2,5
	Athos	18	22	16	19	9	12	13	11	15.0	R 2,5
	Goldmarker	13	24	16	23	14	16	16	9	16.4	R 3,4
	Uta	33	37	22	23	27	23	25	17	25.9	R 2,5
	Porthos	29	34	25	22	30	28	25	22	26.6	R 2,5
	Aramir	34	41	24	30	35	27	22	28	30.0	R 2,5
	Proctor	33	38	33	30	28	32	31	24	30.9	R 0
	Ark Royal	36	40	34	27	38	30	28	30	32.8	R 6
	Printa	34	43	26	36	36	38	29	24	33.3	R 2,5
	Lofa Abed	33	43	37	30	38	38	32	27	34.6	R 4
	Ambre	34	42	36	32	42	37	37	24	35.2	R 4
	Firecrest	35	36	42	31	37	35	40	32	36.0	R 6
	Midas	40	44	34	35	42	44	30	26	36.7	R 3
	Jupiter	39	45	35	27	41	43	39	35	37.9	R 3,4
	Armelle	36	41	34	34	41	42	37	42	38.3	R 2
	Mala Abed	43	48	37	31	44	33	35	36	38.4	R 4
	Dram	44	46	36	32	35	39	36	46	39.3	R 4,6
	Wing	48	50	42	36	39	43	35	36	41.0	R 6
	Minak	49	51	40	32	45	48	33	43	42.5	R 3,4
	Tyra	41	48	40	39	46	51	39	38	42.9	R 7
	Magnum	43	50	42	44	40	50	38	40	43.4	R ?
	Albion	49	54	43	39	46	54	37	41	45.5	R 8
	Georgie	46	47	45	43	41	47	42	43	44.2	R 2,4
	Universe	48	51	45	43	45	51	39	50	46.4	R 2,4
	Berac	53	58	41	40	45	60	41	43	47.5	R 2
	Vada	48	55	44	39	51	59	45	40	47.7	R 4
	Keg	55	55	45	50	46	58	45	52	50.6	R 6
	Luke	55	60	51	50	53	55	43	39	50.7	R 2,4
L S D	(P = 0.05)	8	14	7	8	9	10	9	10		

Table 4. Frequency of individual virulences

V factor	Common name	1975[1)]	1976[2)]	1977[2)]
V 1	Astrix virulence	97	17/17	27/27
V 2	Bigo virulence	3	0/17	3/17
V 3	Varunda virulence	11	0/17	3/17
V 4	Mazurka virulence	6	0/17	4/17
V 5	Sultan virulence	98	17/17	27/27

1) percentage frequency from seedling tests with 69 isolates

2) number of virulent isolates as fraction of total tested on seedlings

as an indication of relative incompatibility. Resistance factors effective against barley mildew have been included for comparative purposes in Table 3.

The frequency of various individual virulences in the U.K. population in 1975, 1976 and 1977 is given in Table 4. Sampling was not carried out on a random basis and therefore the estimated frequencies may not reflect the true frequency in the U.K. population. The number of samples collected in 1976 and 1977 is probably inadequate for estimating virulence frequency with an acceptable degree of precision. For these years, virulence frequency has been expressed as the number of virulent isolates as a fraction of the total tested on seedlings.

Astrix virulence (V 1)

R 1 is possessed by a number of commercial cultivars, eg Julia, Zephyr, Sundance and Abacus, but is almost completely ineffective owing to the high frequency of V 1 in the U.K. population. R 1 is effective at both seedling and adult plant growth stages and thus is of the 'overall' type (Zadoks, 1961). All cultivars found to possess R 1 also possess the mildew resistance R 2 ('Mlg'), indicating possible linkage between these resistances. However, some cultivars, eg Berac and Armelle, possess mildew R 2 but lack yellow rust R 1.

Bigo virulence (V 2)

Virulence for R 2 has apparently only been detected in India (1969) and the U.K. (1975). In the U.K., the frequency of V 2 has remained low since 1975.

Varunda virulence (V 3) and Mazurka virulence (V 4)

A comparison of seedling and adult plant test results indicate that the differential effect of R 3 and R 4 is expressed less clearly in adult plants than in seedlings. On seedlings of both cultivars, a clear distinction can be made between virulent isolates (type 4; abundant sporulation, no chlorosis) and non-virulent isolates (type 2; reduced sporulation, chlorosis). Adult plants of Varunda produced variable reaction types and no distinction could be made between previously classified virulent and non-virulent isolates. Adult plants of Mazurka produced type 4 reactions to all isolates. Resistance to P. striiformis that is expressed more effectively in seedlings than adult plants is rare. They could be classified as 'seedling' resistances to comply with the use of the terms 'overall' and 'adult plant' resistance (Zadoks, 1961).

Sultan virulence (V 5)

R 5 appears to be almost completely ineffective against the present U.K. population of P. striiformis.

Virulence for Hassan and Maris Mink

The adult plant tests indicate that Hassan and Maris Mink may possess a specific resistance different from R 1 - 5. Virulence compatible with this resistance seems to be carried by all the isolates except 75/101. The presence of this resistance in these cultivars requires confirmation.

Virulence for other cultivars

The adult plant tests indicate that cultivars differ widely in their levels of apparently non-specific resistance. Cultivars possessing the mildew resistances R 2,5 ('Mlg' + 'Mlas') are more resistant than most in this respect. This resistance to P. striiformis may derive from Emir which is still apparently resistant world wide. The mildew resistances R 6 ('Mla4/7'), R 7 ('Mla') and R 8 ('Mla9') appear to have little effect on P. striiformis.

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BROWN RUST OF BARLEY

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

Welsh Plant Breeding Station, Aberystwyth

R.H. Priestley

National Institute of Agricultural Botany, Cambridge

Of the 50 samples of *Puccinia hordei* (Otth) received in the 1977 survey, 36 were successfully tested on the standard set of differential varieties which carry genes Pa to Pa_9. The common race F was recorded most frequently (Pa, Pa_2, Pa_4, Pa_5, Pa_6, Pa_8 virulent), the only other race identified being similar to race F but with additional virulence to Pa_9.

Comparative tests of adult plants inoculated with specific isolates in the field nurseries and in Polythene tunnels confirmed that isolates from a field of the variety Armelle and from the variety Lofa Abed showing higher than expected infection levels were not specifically adapted to their parent varieties. Varieties with partial resistance to *P. hordei* commonly carry either Mlv or Mlas resistances to *Erysiphe graminis*.

1977 SEEDLING DIFFERENTIAL TESTS (WPBS)

Of the 50 samples received, 11 came from winter and 39 from spring varieties. The isolates were tested on a standard set of differentials which carry the Pa genes 1 to 9 (Clifford and Jones, 1977). Fourteen samples failed to culture and of the remainder, 9 from the winter varieties and 23 from the spring varieties were of a race which carries virulence to Pa, Pa_2, Pa_4, Pa_5, Pa_6 and Pa_8. This is the common race F of previous surveys. Only one other race was identified, twice on winters and twice on spring varieties and is similar to race F but carries additional virulence to Pa_9 which governs resistance in CI 1243 (Udeogalanya and Clifford, 1978) and apparently in the variety Triumph.

The majority of winter variety samples (9) came from the Norfolk Agricultural Station, Morley and 37 of the 39 spring variety samples were from WPBS/ADAS Cooperative Trap Nurseries sown in Devon and Cornwall. These nurseries were planted to monitor brown rust populations in the south west with regard to virulence on partially resistant varieties such as those in Groups 1, 2 and 3 below. Unfortunately, the generally low levels of brown rust infection in the south west and elsewhere in 1977 prevented any assessments of quantitative variety x race interactions.

1977 BARLEY BROWN RUST ISOLATION NURSERIES (WPBS)

Twenty spring varieties which differ in their degree of susceptibility ('slow rusting') to Puccinia hordei under field and experimental conditions were grown as replicated clumps in isolated field nurseries, and inoculated with one of 5 specific isolates of P. hordei.

The varieties used may be grouped according to their relationships by breeding and their purported brown rust resistance, thus:

Group 1 (Vada resistance)	Group 2 (Emir resistance)	Group 3 (Unknown resistance)	Group 4 (Susceptible)
Lofa Abed	Hassan	Armelle	Mazurka
Abacus	Maris Mink	Tyra	Wing
Julia	Aramir		Proctor
Georgie	Tintern		Ark Royal
Sundance			Midas
Varunda			RMH - 1
Vada			RMH - 2

The isolates used were:

1)	BRS - 76 - 12	Pa, Pa_2, Pa_3, Pa_4, Pa_5, Pa_6, Pa_8, Pa_9 virulent
2)	Race F	Pa, Pa_2, Pa_4, Pa_5, Pa_6, Pa_8 virulent
3)	BR/C 479/C	Vada virulent
4)	BRS - 76 - 5	Ex Lofa Abed
5)	BRS - 76 - 6	Ex Armelle

Similar levels of disease developed in each of the nurseries and no significant race x variety interactions were detected. In particular, the isolates from the varieties Armelle and Lofa Abed were not adapted to those varieties indicating that the observed high levels of infection on single fields of those varieties in Cornwall in 1976 were probably due to unusual environmental conditions relating to the dry, hot weather.

1977 POLYTHENE TUNNEL TESTS (NIAB)

A range of varieties, including many of those listed in the above groups, were tested against a range of isolates of P. hordei in Polythene tunnels. The isolates used were supplied by the WPBS and were as follows:

1.	BR/CI 1243	CI 1243 (Pa_9) virulent
2.	BR/C 479/C	Vada virulent
3.	BRS/76 - 12	Pa_3 virulent
4.	BRS/76 - 6	ex Armelle
5.	Race F	Pa, Pa_2, Pa_4, Pa_5, Pa_6, Pa_8 virulent
6.	BRS/76 - 5	ex Lofa Abed

RESULTS

The results are given in Table 1. R factors for resistance to barley mildew are given for comparative purposes.

Levels of P. hordei produced by BRS/76 - 6, Race F and BRS/76 - 5 were much lower than those produced by the other 3 isolates. This may be due to a true difference in aggressiveness or may simply reflect differences in inoculum quality. The Race F isolate is known to be aggressive in the field compared with BR/C479C and in the field tests reported above Race F, BRS/76 - 5 and BRS/76 - 6 were similarly aggressive.

Significantly positive interaction residuals were produced by Goldmarker and Minak against the 'Vada virulent' isolate, and by these cultivars plus Sultan and Albion against the 'CI 1243 virulent' isolate. This result needs to be confirmed before any firm conclusions are drawn.

There was no evidence of any adaptation of the Armelle isolate to Armelle, nor the Lofa Abed isolate to Lofa Abed and this confirms the Isolation Nursery data.

It was noted that the reaction types produced by the 'Pa_3 virulent' isolate on the cultivars Porthos, Athos, Printa, Uta, Hassan (all contain mildew resistance R 5) and Georgie, Dram (both contain mildew resistance R 4) were higher than those produced by the other isolates, whereas the reaction type of Midas was similar to all isolates.

In general, cultivars containing the mildew resistance R 5 ('Mlas') and R 4 ('Mlv') are more resistant than most. Sultan (R 5), Goldmarker and Minak (both R 3, 4) are exceptions to this.

Table 1. 1977 Brown rust of barley Polythene tunnel test data

Sowing date: 17 March 1977 Inoculation date: 27 April 1977
Assessment dates: 26 April (GS 31), 10 May (37-39), 24 May (45-56), 31 May (58-64) and 9 June (60-68)

Values are mean percent leaf area infection (2 replicate tussocks, 5 dates). Underlined values have significantly (P = 0.05) positive two-factor residuals indicating a large positive interaction between cultivar and isolate.

Test cultivar	Isolate: 'CI 1243 virulent'	'Vada virulent'	'Pa_3 virulent'	BRS/7616 (ex Armelle)	Race F	BRS/76-5 (ex Lofa Abed)	Mean	Mildew R factors
Sultan	27	16	24	5	6	3		R 5
Albion	25	28	19	5	6	4		R 8
Goldmarker	27	24	13	4	7	3		R 3,4
Minak	35	20	21	2	4	2		R 3,4
Sundance	3	2	3	1	0	0	1.6	R 2,4
Athos	2	1	8*	0	0	0	1.9	R 2,5
Georgie	3	2	5*	1	0	1	2.1	R 2,4
Armelle	3	4	6	0	0	0	2.3	R 2
Ambre	4	2	8	1	0	1	2.5	R 4
Porthos	2	2	9*	0	1	0	2.5	R 2,5
Vada	3	3	7	0	1	2	2.6	R 4
Varunda	5	7	4	0	0	0	2.8	R 4
Abacus	3	4	8	1	1	2	2.9	R 2,4
Mala Abed	2	5	8	0	1	1	2.9	R 4
Firecrest	4	2	9	1	1	1	3.0	R 6
Magnum	7	4	5	1	1	1	3.1	R ?
Hassan	4	2	11*	1	1	1	3.2	R 5
Luke	5	5	8	1	1	1	3.5	R 2,4
Maris Mink	5	7	12	1	1	1	4.3	R 2,5
Universe	8	9	7	1	1	2	4.6	R 2,4
Uta	5	6	16*	0	2	1	4.9	R 2,5
Jupiter	9	11	8	1	1	1	5.0	R 3,4
Printa	6	4	13*	4	2	2	5.1	R 2,5
Julia	10	8	11	1	1	3	5.6	R 2
Lofa Abed	9	12	9	1	2	1	5.6	R 4
Keg	11	6	11	2	3	1	5.7	R 6
Aramir	11	7	13	3	2	3	6.7	R 2,5
Dram	8	8	20*	1	3	2	7.0	R 6
Berac	10	13	18	2	5	3	8.3	R 2
Wing	9	17	20	2	4	3	9.1	R 6
Ark Royal	18	14	20	2	3	1	9.4	R 6
Mazurka	10	17	20	3	5	2	9.5	R 2,6
Tyra	13	19	20	1	5	3	10.3	R 7
Proctor	17	21	21	3	4	3	11.5	R 0
Zephyr	24	30	32	5	11	6	17.9	R 2
Midas	32	28	31	19	12	9	21.8	R 3
LSD (P = 0.05)	5	5	5	3	3	3		

* higher reaction type than with other isolates

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BROWN RUST OF WHEAT

B.C. Clifford, E.R.L. Jones
Welsh Plant Breeding Station, Aberystwyth

& R.H. Priestley
National Institute of Agricultural Botany, Cambridge

Twenty-two samples of Puccinia recondita were received. Seedling tests with isolates made from the samples have confirmed the presence of virulence for wheat-rye derivatives. The cultivars Sappo and Maris Halberd, previously thought to possess the same resistance, are now thought to possess different resistances provisionally numbered R 3 and R 4.

Race nurseries grown either in the field or enclosed in Polythene tunnels have confirmed the presence of R 2 in Maris Fundin and R 5 in Maris Huntsman and Maris Nimrod. One isolate (76/1) produced a higher infection level than other isolates on Maris Ranger indicating a possible increase in virulence for this cultivar. Further tests will be carried out to confirm this observation. A number of other cultivars were found to possess widely different levels of apparently non-specific resistance of the 'slow rusting' type and this may prove to be relatively durable.

SEEDLING TESTS WITH 1977 ISOLATES

Twenty-two samples were received at the Welsh Plant Breeding Station (WPBS). Twelve were collected from selected cultivars in WPBS isolation nurseries, four were from crops of Maris Huntsman in Herefordshire, and one each was from Flanders, Highbury, RPB 477/71, Sappo, Clement and Aquila.

The results of the seedling tests are shown in Table 1. Many isolates gave mixed reactions on some cultivars which makes interpretation difficult, nevertheless a number of conclusions could be drawn.

A number of isolates either produced a virulent or mixed virulent/non-virulent reaction on Forester, Stuart, Magister, Donata and Hedgehog. These cultivars along with Clement evidently derive their resistance from the wheat-rye translocation line Riebesel 47/51. The results therefore confirm the detection of virulence for wheat-rye derivatives by Dr Chamberlain (personal communication).

The cultivars Sappo and Maris Halberd, previously thought to possess the same resistance, were differentiated by isolate 77 - 15. These resistances have been provisionally allocated the symbols R 3 (Sappo) and R 4 (Maris Halberd).

Virulence for Sterna was found in isolate 77 - 12. This virulence has been found previously, but only rarely.

Some isolates (e.g. 77 - 12 and 77 - 15) were widely virulent compared with other, (e.g. 77 - 21 and 77 - 22).

ADULT PLANT TESTS WITH 1976 and OLDER ISOLATES

Race nurseries, either sown in isolation from one another in the field at WPBS or in Polythene tunnels at Cambridge (NIAB), were used to investigate the adult plant response of various cultivars to a number of isolates of Puccinia recondita.

At WPBS, the cultivars were sown as 30 cm^2 clumps spaced 70 cm apart in each direction. Four replicates of each of 20 cultivars were randomized in a 10 x 8 arrangement. Clumps of infected seedlings were transplanted into the pathways equidistant from four test clumps thus ensuring equal opportunity of infection by the test plants. The nurseries were isolated from each other by a distance of at least 25 m. The material was autumn sown, infected seedlings were transplanted into the nurseries in mid - May and assessments of percentage leaf area infected and reaction types were made on 7 July and 18 July.

At NIAB, race nurseries were sown within Polythene tunnels 5.2 m long, 4.3 m wide and 2.2 m high. Each tunnel was provided with overhead irrigation. The temperature within a tunnel could be controlled to within 5°C of ambient by removing Polythene panels to increase ventilation. The tunnels provided a humid atmosphere that promoted rapid epidemic development and also minimised cross contamination between isolates in adjacent nurseries. Cultivars were sown as 230 mm diameter tussocks with 230 mm between tussocks. Two replicate tussocks of each cultivar were sown in a 6 x 12 arrangement using a randomization balanced in two directions. The tussocks were sown on 16 November, inoculated on 28 February and 21 March and assessed for percentage leaf area infection on 26 April (GS 31), 10 May (37 - 39), 24 May (45 - 56), 31 May (58 - 64), 9 June (60 - 68) and 16 June (68 - 75). The isolates used and details of their origins are given in Table 2.

Table 1. Seedling test results (1977)

Isolate WBR - 77 -

Differential	-1	-2	-3	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22
Hobbit	M	M	R	R	M	M	R	S	S	M	S	S	S	S	M	S	M	S	M	R	R
Sterna	R	M	R	M	R	R	R	M	M	R	S	R	R	M	R	R	R	R	M	R	R
Sappo	S	M	M	R	S	S	M	M	S	R	M	S	M	S	S	-	M	-	M	R	R
Halberd	S	M	M	S	M	S	M	-	-	M	M	S	-	R	-	-	R	-	-	R	R
Anfield	S	M	M	M	M	S	M	M	M	R	M	S	M	S	M	S	M	S	S	R	R
Highbury	S	S	S	M	M	S	S	M	M	S	S	S	S	S	M	S	S	S	M	R	M
TW 238/14	M	S	R	M	M	M	M	M	M	M	M	S	M	M	S	R	M	S	S	R	R
TW 238/62	M	S	M	M	M	S	M	M	M	M	M	S	M	S	S	R	M	R	S	R	M
Sportsman	S	S	S	S	S	S	R	S	S	S	S	S	S	S	S	S	S	S	S	S	S
RPB 1158	R	M	R	S	M	M	M	M	S	R	R	R	M	S	M	R	R	M	R	S	S
Forester	R	R	R	S	S	S	M	R	M	M	S	R	R	S	M	R	R	S	S	S	S
Stuart	R	M	R	M	M	M	M	R	S	R	S	R	M	S	R	R	S	S	M	S	S
Magister	R	M	R	S	S	M	M	R	M	R	S	R	M	S	M	M	M	M	R	S	S
Donata	R	M	M	M	M	M	M	R	M	R	M	R	R	S	R	R	S	M	M	S	S
Hedgehog	S	M	R	M	S	M	M	M	M	R	S	R	R	S	R	R	S	M	R	S	S

R = Resistant S = Susceptible M = Mixed

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

Isolate code	Origin	
	Cultivar	Region
WBR 74/ 2	Maris Huntsman	Morley, Norfolk
WBR 74/11	Maris Fundin	Seale Hayne, Devon
WBR 76/ 1	Rye cultivar	Aberystwyth, Dyfed
WBR 76/11	Sportsman	Aberystwyth, Dyfed
WBR 76/28	Sappo	Leixlip, Eire
Mix	Mixture of 20 isolates from compatible pustules on Maris Ranger, Hobbit, Kinsman and Sportsman in Polythene tunnel tests at NIAB in 1976.	

The results are summarised in Table 3. High levels of infection developed both in the isolation nurseries and in the Polythene tunnels although higher levels generally developed in the Polythene tunnels on the very susceptible cultivars. The boxes in the table indicate relatively low infection levels on a particular cultivar compared with those produced by other isolates in the same type of test. They thus indicate relative incompatibility on the basis of a negative interaction between cultivar and isolate. Specific resistances have been given the symbols R1 - 5. The genes responsible for these phenotypic responses are not known. Resistances have been classified as 'overall' (effective at all growth stages) or 'adult plant' (effective at adult plant growth stages only) (after Zadoks).

None of the isolates tested was virulent on Clement or Forester (R1). Those isolates possessing virulence for seedlings of these cultivars have not yet been evaluated on adult plants.

The results confirm the presence of the overall resistance R2 in Maris Fundin described by Clifford, Jones and Priestley (1977). The limited evidence available indicates that Maris Bilbo may also possess this resistance. Previous tests have shown that the expression of R2 in seedlings of Maris Fundin is environmentally sensitive.

The results also confirm the presence of R5 in Maris Huntsman and Maris Nimrod. Previous tests have shown that R5 is ineffective at the seedling stage and is thus a resistance of the adult plant type (Clifford et al., 1977).

Table 3. Mean percentage leaf area infection values for wheat cultivars inoculated with isolates of P. recondita

Resistance factor	Cultivar	74/2 RN	74/2 PT	74/11 RN	74/11 PT	76/1 RN	76/11 RN	76/28 RN	Mix* PT
R1	Clement	.	0	.	0	.	.	.	0
	Forester	0	.	0	.	tr	0	0	.
R2	Maris Fundin	8	9	17	23	19	19	11	29
	Maris Bilbo	.	3	.	24	.	.	.	29
R5	Maris Huntsman	18	25	7	12	20	17	14	25
	Maris Nimrod	16	30	8	17	16	20	16	34
	Mardler	.	19	.	6	.	.	.	26
R2, + ?	Hobbit	7	1	3	0	4	5	5	3
	Maris Ranger	1	3	4	3	12	2	8	5
	Kinsman	0	2	0	1	tr	tr	tr	2
	Sportsman	5	0	9	0	5	5	12	1
	Flinor	6	7	13	7	16	15	16	13
	Cappelle-Desprez	10	9	15	8	14	14	14	13
	Maris Freeman	12	12	16	10	20	13	13	12
	Champlein	11	8	16	11	21	17	16	17
	Atou	13	8	13	12	18	16	12	17
	Mega	10	9	13	13	18	12	9	16
	Waggoner	13	10	9	16	16	11	8	13
	Maris Widgeon	11	12	15	14	16	17	12	22
	Flanders	14	16	17	22	20	17	14	20
	Bouquet	9	13	11	20	15	11	9	26
	Armada	18	22	17	37	23	21	20	42
	Highbury	8	.	11	.	15	14	11	.
	Hustler	.	0	.	0	.	.	.	0
	Aquila	.	1	.	1	.	.	.	1
	Fleurus	.	1	.	10	.	.	.	6
	Kador	.	14	.	9	.	.	.	10
	Maris Templer	.	4	.	14	.	.	.	18
	Valmy	.	7	.	16	.	.	.	16
	Grenade	.	13	.	19	.	.	.	19
	Val	.	15	.	20	.	.	.	23
	Joss Cambier	.	16	.	28	.	.	.	27
	Hawk	.	15	.	27	.	.	.	30
	Rothwell Perdix	.	16	.	29	.	.	.	29
	Score	.	20	.	25	.	.	.	32
	Tommy	.	18	.	29	.	.	.	35
	Maris Beacon	.	28	.	29	.	.	.	33
	Michigan Amber	.	46	.	35	.	.	.	40

. not tested
RN race nursery
PT race nursery in Polythene tunnel

Hobbit probably possesses R 2 in combination with another resistance. In previous tests, Hobbit has reacted in a similar way to Maris Fundin at the seedling stage which suggests that it possesses R 2. It also contains additional resistance which is effective in the adult plant stage and which is different to that of Maris Fundin and Maris Huntsman. This is indicated by isolates 76/1 and 76/11 which were virulent on Fundin and Huntsman but avirulent on Hobbit in the race nursery tests.

Isolate 76/1 produced a higher infection level than any other isolate on Maris Ranger indicating a possible increase in virulence for this cultivar. Further tests are being carried out to confirm this observation. Kinsman was highly resistant to all isolates and frequently exhibited an immune reaction type. A number of other cultivars (including Cappelle - Desprez, Mega, Bouquet, Flinor, Maris Widgeon, Waggoner, Highbury and Atou) have shown high levels of partial resistance in these and previous tests. Relatively low infection levels occur on these varieties with all isolates tested, although a compatible host : pathogen interaction occurs. Such 'slow rusting' resistance may be more durable as appears to be the case will similarly expressed resistance of barley to _P. hordei_ (Clifford, Jones and Priestley, 1978).

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CROWN RUST OF OATS

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

Welsh Plant Breeding Station, Aberystwyth

Three races were identified from the five samples successfully cultured. Of these, race 251 and 289 had been previously recorded but the identification of race 393 from Cornwall and Hampshire was new for Britain. Race 393 carries virulence to the differential varieties Victoria, Appler, Bond and Saia.

Out of a total of 39 samples received, 36 were from a Welsh Plant Breeding Station oat disease nursery in Gwithian, Cornwall. Unfortunately, postal delays resulted in the samples arriving in poor condition and only two samples were successfully cultured. One of these was identified as race 289 and the other as race 393 which was previously unrecorded in Britain and occurred on the breeding line 03032 Cn2. This latter race was also identified from a sample of the winter variety Maris Quest grown at Sparsholt, Hampshire. Also received from Sparsholt were samples from the winter cultivars Panema and Pennal both of which were identified as the common race 251. The virulence spectra of the identified races are given in the table.

Differential variety	Race		
	251	289	393
Anthony	R	R	R
Victoria	R	R	S
Appler	S	S	S
Bond	S	R	S
Landhafer	R	R	R
Santa Fé	R	R	R
Ukraine	R	R	R
Trispernia	R	R	R
Bondvic	R	R	R
Saia	S	S	S

R = Resistant S = Susceptible

MILDEW OF BARLEY

M. S. Wolfe and Susan E. Wright
Plant Breeding Institute, Cambridge

Several varieties, including three new varieties on the Recommended List, were confirmed as possessing the resistance combination BMR 3+4 (Barley Mildew Resistance groups 3+4), which is the combination of resistance from varieties, for example, such as Midas and Lofa Abed.

Further analysis of isolates from Tyra confirmed that it had resistance (probably Mla) derived from Algerian, and not from Monte Cristo (Mla4/9). Several varieties with resistance derived from Monte Cristo were placed in group BMR 8.

The population structure of the pathogen on different varieties remained similar to that in the previous two years, although there was some evidence of an increase in the frequency of isolates with combined virulence for BMR5 and BMR6.

A total of 132 samples was received, including ten from winter varieties.

New virulence identification

Table 1 shows the number of samples received in each of the host resistance groups together with the appropriate BMR group (Barley Mildew Resistance group) to which some previously unassigned varieties belong.

Table 1. BMR group definitions and numbers of barley mildew isolates received in 1977

BMR Group	Gene	No. samples	Variety examples
0	-	3	Golden Promise, Hoppel
1	'Mlh' (2 genes)	4	a) Igri, Malta, Sonja (41/145)
			b) Astrix, Athene, Senta (37/136+41/145)
2	'Mlg' (2 genes)	6	Julia, Katy, Zephyr
3	'Mla6'	-	Midas
4	'Mlv' (2 genes)	8	Ambre, Mala Abed, Lofa Abed
5	'Mlas'	1	Hassan, Piccolo, Baltsar
6	'Mla4/7' (2 genes)	10	Ark Royal, Firecrest, Keg, Wing
7	'Mla'	9	Tyra
8	'Mla4/9' (2 genes)	7	Akka, Albion, Welam, WR73294, W6542, W6495
n	'Mlar'	-	Rupal
2+4		13	Georgie, Sundance, Luke
2+5		24	Aramir, Athos, Cornel, Porthos, Printa, Uta
2+5+?		7	Maris Mink
2+6		-	Mazurka
3+4		14	Goldmarker, Goldspear, Jupiter, Minak, Sovereign
4+?		7	Magnum
6+(Ab12)		-	Triumph
6+?		3	Dram

- = no isolate received

There are a number of modifications in Table 1, compared with a similar Table in the Report for 1976. In BMR1 two sub-groups can now be defined among the winter barleys, namely, those that carry the resistance gene which is present alone in the line Weihenstephan 41/145, and those that possess this gene in combination with the gene which is also present alone in Weihenstephan 37/136. Both genes were derived from Ragusa b, the original source of mildew resistance used in winter barleys. This differentiation has little obvious value for diversification purposes since both of the corresponding virulence genes are common in the pathogen population. It should be pointed out, however, that Athene is more resistant in the field than the other varieties, but the origin of this resistance is not known.

The variety Tyra, allocated to BMR7, was found to be unrelated to the Monte Cristo resistance source, and this was confirmed by the breeder. The mildew resistance of Tyra comes from the variety Algerian, which has at least three resistance genes: Tyra probably possesses only Mla (see also Torp et al, 1978). Varieties with resistance derived from Monte Cristo have been reallocated to BMR8. Within this group it was confirmed that Akka (Mla4/9) does not possess BMR2 resistance as had been previously thought, since it was fully susceptible to a new isolate lacking BMV2 (Barley Mildew Virulence group 2).

A new group, BMR3+4 is introduced, which contains three Recommended List varieties, namely, Goldmarker, Jupiter and Minak. Virulence for this combination is currently uncommon in the pathogen population.

Although highly resistant to most isolates with which it has been tested, there is evidence from some reactions, and from its pedigree, that Magnum possesses BMR4 in combination with an unknown source of resistance, which is not mlo; the variety is susceptible to some isolates found in Israel.

The variety Triumph also does not possess the mlo resistance, but combines BMR6 with moderate resistance from the Ethiopian accession Ab 12. The variety is fully susceptible to an isolate identified in Czechoslovakia. Dram also possesses BMR6, but with another source of unidentified background resistance.

Pathogen population structures

Isolates received in the survey are treated as bulks in that they are not separated into single spore or single colony fractions. They are inoculated on to test varieties containing resistance factors which are currently or potentially important, together with the susceptible control, Golden Promise. Counts are made of compatible, sporulating colonies on each of the test varieties, and the isolates compared using the value obtained on Golden Promise as a standard. To obtain virulence frequencies, the assumption is made that each compatible colony represents the occurrence of a pathogen genotype with that particular virulence.

In Table 2 are listed the reactions of bulk isolates in completed tests on seedlings of relevant test varieties. If detailed reactions of any specific isolates are required, please contact the authors.

Table 2. Percentage relative virulence frequencies (assessed as colony numbers) produced by bulk isolates on test seedlings of appropriate BMR group varieties. Isolates non-virulent on the varieties from which they were originally collected have been omitted

BMR Group	Source variety of bulk isolate	Mean percentage virulence frequencies relative to Golden Promise as assessed on test varieties													No. of virulent isolates
		1	2	3	4	5	6	7	8	2+3	2+4	2+5	2+6	3+4	
0	Hoppel	50	80	2	1	35	52	0	0	2	0	35	54	0	2
1	Athene	49	82	1	0	34	2	0	0	1	7	94	4	0	2
	Igri	35	51	17	0	20	29	0	0	27	2	31	57	0	2
	Malta	17	40	1	0	33	14	16	0	1	0	58	25	0	2
2	Katy	56	51	13	0	14	68	0	0	6	0	25	38	0	1
	Julia	83	65	2	1	20	0	0	0	7	0	27	0	0	1
4	Mala Abed	32	35	4	34	19	0	0	0	1	17	15	0	1	3
	Ambre	39	44	24	32	7	0	7	0	7	42	0	0	12	1
5	Hassan	17	40	0	0	41	13	0	0	0	2	37	61	0	1
6	Wing	12	54	31	0	15	54	0	0	27	10	31	62	0	1
	Ark Royal	136	57	0	2	10	84	0	0	0	0	9	57	0	1
	Keg	35	48	4	0	7	58	0	0	3	0	21	79	0	2
	Firecrest	38	63	3	2	14	64	0	0	1	1	7	63	0	4
7	Tyra	37	64	22	9	18	5	57	0	23	2	37	7	0	7
8	Albion	50	84	1	2	3	58	0	40	1	1	19	76	0	3
	WR73294	18	73	10	0	2	36	0	44	0	1	0	89	0	1
	W6542	32	76	0	13	5	53	0	54	0	0	5	57	0	1
	W6495	36	2	0	3	0	70	0	74	0	0	0	0	0	1
2+4	Georgie	39	59	14	36	13	0	0	0	11	34	30	0	7	4
	Sundance	37	80	19	45	8	0	0	0	18	107	40	0	5	1
2+5	Aramir	35	72	8	3	49	4	0	0	7	12	79	4	1	6
	Athos	36	76	7	4	32	4	5	0	5	2	73	5	0	7
	Porthos	39	54	0	46	75	0	0	0	0	41	54	0	0	1
	Printa	36	68	3	0	38	20	3	5	3	8	86	34	0	3
	Uta	30	74	1	0	39	1	0	0	1	0	80	8	0	2
	Maris Mink	41	95	19	27	30	9	0	0	15	0	58	4	0	5
3+4	Minak	33	56	65	40	2	2	0	0	43	33	24	0	22	2
	Goldmarker	41	44	57	36	13	0	0	0	52	39	13	0	36	3

From this and similar Tables in the 1975 and 1976 reports it is possible to construct progress Tables on the pathogen population structures occurring on each BMR group. Table 3 shows the frequency of occurrence of all virulences on each of the BMR groups, thus indicating the degree to which each BMR group can act as an infection source for other BMR groups. For example, from the columns in Table 3, BMV1 and BMV2 are relatively common on all varieties, therefore the corresponding varieties in BMR1 and BMR2 are likely to be infected wherever they are grown. On the other hand, all other BMV frequencies tend to be low (except of course on their corresponding host group), which means that, from BMR3 upwards relatively few spores are being generated which carry combined virulences for more than one BMR group.

Reading across Table 3 it can be seen that several virulences are relatively common on BMR1 though BMV3 and BMV6 appear to be declining, and BMV5 and BMV2+5 increasing. Indeed, BMV3 appears to be declining generally, a trend which began after the commercial failure of the variety Impala (BMR2+3) at the beginning of the decade. This decrease in BMV3 may be arrested, of course, if the BMR3+4 group varieties become popular and susceptible. BMV6 appears to be increasing on BMR2, which may reflect the common occurrence of the BMV2+6 combination on all BMR6, and BMR8, varieties.

The current low frequency of BMV4 may also increase following greater popularity of newer varieties which have BMR4 combined with other resistances, i.e. BMR2+4, BMR3+4 and Magnum.

An important feature of the BMR5 and BMR6 populations is whether or not the apparent increase in frequency of BMV5+6 is real (i.e. BMV6 on BMR5, and BMV5 on BMR6). The selection pressure for such an increase is enormous since approximately half of the barley acreage has either BMR5 or BMR6.

Almost the only occurrence of BMV8 other than on its own host was on BMR6, and, conversely, BMV6 occurs with an unusually high frequency on BMR8. These events reflect the relationship of BMR6 and BMR8 in that they possess one resistance gene in common i.e. the 'HOR 1063' gene, also known as Mla4. The higher frequency of BMV6 on BMR8 compared with BMV8 on BMR6 reflects the order of introduction and relative popularity of BMR6 and BMR8. Thus, it is of greater benefit to the small pathogen population on the small area of BMR8 to be able also to grow on BMR6 varieties, than the reverse.

The first larger scale observations on the population being selected by BMR7 indicate a higher than expected frequency of BMV3 and BMV2+5, although

Table 1. Wheat Mildew Resistance Groups

WMR Group	Gene	Source	Varieties
0	Effectively nil	Various	Minister, Atou, Hobbit
1	Pm1	Marquisxunknown var,	Axminster, Anfield
2	Pm2	CI12632, CI12633	Ulka, Sportsman, Wizard
3	Pm3	a: Japanese var. b: Russian var. c: Mexican var.	Asosan Chul Sonora
4	Pm4b	*Triticum carthlicum*	Weihenstephan M1, Cardinal
5	Pm5	Yaroslav emmerxMarquis	Hope, Redcoat
6	Pm6	*Triticum timopheevi*	Timgalen, Mengavi
7	Pm8	*Secale cereale*	Salzmünde 14/44, Clement Nautica
8	Undetermined	Unknown (Ibis?)	Mega, Flanders, Waggoner
9	Pm2+'Mld'	*Triticum durum*	Halle 13471, Maris Dove
2+4	-	-	Sappo, Armada
2+6	-	-	Maris Fundin, Maris Huntsman
5+8*	-	-	Sicco
2+4+6*	-	-	Walter, Timmo

*Yet to be confirmed

General observations

A total of 86 samples was received from 31 winter and 4 spring wheat varieties. As in previous years, the samples were inoculated as bulk isolates to a set of differential varieties and the frequencies assessed as colony numbers. In the tables these frequencies have been expressed as percentage relative frequencies, the number of colonies on Minister (the WMR0 differential) being taken as 100 per cent in each test. Table 2 shows the reactions of 64 of these bulk isolates on seedlings of relevant test varieties.

Table 2. Percentage relative frequencies of virulences in bulk isolates received in 1977

WMR Group	Source variety	Percentage virulence frequencies relative to Minister Wheat Mildew Virulence (WMV) Group													Number of Isolates
		1	2	4	5	7	8	9	2+4	2+6[1]	2+6[2]	5+8	2+4+6[3]	2+4+6[4]	
0	Atou	96	51	0	83	3	117	5	0	21	0	128	0	0	2
	Bouquet	40	48	0	94	0	121	0	0	8	0	82	0	0	2
	Chalk	80	125	0	16	0	31	53	0	1	0	13	2	0	2
	Eloi	164	0	0	10	0	32	0	0	31	0	0	0	0	1
	Flinor	69	91	0	135	0	85	5	0	0	0	50	0	0	1
	Freeman	90	92	0	65	14	82	126	0	5	2	96	0	0	1
	Hobbit	27	114	0	23	0	37	46	0	28	3	1	0	0	2
	Holdfast	19	16	0	27	0	48	2	0	0	0	0	0	0	1
	Iona	34	81	65	39	0	27	92	51	50	17	7	34	28	1
	Little Joss	0	21	0	85	0	57	25	0	0	0	9	0	0	1
	Rampton Rivet	120	17	0	23	0	5	14	0	39	0	0	0	0	1
	Ranger	89	29	11	20	0	42	14	17	17	9	4	8	10	3
	Widgeon	136	162	0	121	0	80	65	0	8	0	91	0	0	1
2	Bounty	94	98	76	10	0	24	89	85	43	11	2	46	47	1
	Nimrod	113	135	0	42	0	50	63	0	0	0	0	0	0	1
	Sportsman	97	167	70	24	4	50	65	52	15	2	24	10	19	5
	Wizard	76	148	0	6	1	21	155	0	0	0	0	0	0	2
7	Clement	152	3	0	0	190	0	0	0	0	0	0	0	0	1
	Nautica	117	0	0	0	95	0	0	0	0	0	0	0	0	1
8	Flanders	0	87	0	74	0	94	0	0	8	0	0	0	0	1
	Rivoli	100	89	90	74	0	72	84	110	11	1	76	34	13	1
	Waggoner	159	70	0	92	0	99	0	0	9	0	84	0	0	2
2+4	Armada	136	115	99	72	0	70	92	110	0	0	79	14	2	2
	Sappo	127	199	248	19	2	16	119	123	36	20	12	55	61	2
2+6	Fundin	62	90	0	41	2	37	2	0	80	43	16	0	0	5
	Huntsman	36	142	0	52	0	57	22	8	84	81	44	2	0	4
	Hustler	43	144	0	13	0	19	33	0	56	36	2	0	0	3
	Kinsman	62	86	0	16	0	81	42	0	112	49	0	0	0	4
	Mardler	25	106	0	11	0	9	16	0	45	12	0	0	0	1
	Vantage	118	125	103	30	0	14	113	138	65	36	0	57	114	1
?	Highbury	81	101	0	0	0	69	128	0	121	58	0	19	19	1
	Spartacus	94	11	0	71	3	84	0	0	0	0	2	0	0	1
Tumult	Line 1	151	72	0	19	233	25	0	0	6	22	0	0	0	1
	2	0	21	0	107	0	145	0	0	0	0	0	0	0	1
	3	122	0	0	68	3	80	0	0	0	0	72	0	0	1
	4	155	156	0	101	0	41	0	0	0	0	108	4	0	1
	5	9	7	0	84	0	107	5	0	1	0	0	0	0	1
	Mean	87	51	0	75	47	79	1	0	1	4	36	1	0	
	Mixture	125	0	0	99	0	42	0	0	45	0	38	0	0	1

[1] Maris Fundin, [2] Maris Huntsman, [3] Walter, [4] Timmo

The data show that strong directional selection is exerted by varieties in all the WMR groups except WMR0. This result is to be expected since varieties in the WMR0 group, whilst not possessing readily detectable resistance genes, undoubtedly possess varying levels of some form of incomplete or background resistance, as evidenced by their mildew ratings on the NIAB Recommended List. Thus, the pattern of virulence frequencies observed in samples from such varieties is a reflection of the diverse host genotypes with which this pathogen must interact.

With this consideration in mind, it is striking that WMV1 (Wheat Mildew Virulence Group 1) is so common in samples not only from WMR0 varieties but also from varieties in all the WMR groups represented. As no commercial variety containing the corresponding resistance has been widely grown (as far as is known) and since WMV1 has been consistently common in European race surveys over a long period, it seems probable that this virulence enhances the competitiveness of an isolate. The WMR2+6 group is the only one from which this virulence is rather less common (see Table 3); this observation supports other evidence which suggests that some of the varieties in this group restrict variability in the pathogen.

Three new differentials (Walter, Timmo and Sicco) were introduced to, and three (Asosan, Chul and Sonora) were dropped from the test set. The reactions of several isolates strongly suggested that Walter and Timmo constitute a new WMR group: 2+4+6. Likewise, reactions on Sicco suggest that this variety belongs to WMR5+8. Since none of the varieties has yet been widely grown, it is perhaps surprising that the virulence combinations corresponding to these two new groups should be so generally common in isolates taken from unrelated varieties. In 1976, WMV2+4+6 was only found in one isolate actually taken from Walter. The reason lies in the relatively higher frequencies of the component virulences in 1977. When the component virulence frequencies reach a certain level, we can expect, by simple probability, to pick up the combinations by chance, irrespective of host pressures.

Samples from a number of previously unassigned varieties were received and their reactions on the differentials enabled the varieties to be allocated to WMR groups as follows: Eloi and Iona to WMR0; Bounty and Wizard to WMR2; Nautica to WMR7; Rivoli and Waggoner to WMR8; Armada to WMR2+4; Hustler, Mardler and Vantage to WMR2+6. In some cases it was necessary to conduct confirmatory tests using mildew isolates of known virulence.

The mean percentage relative frequencies of virulences in isolates from the various WMR groups are set out in Table 3. The means are unweighted in order to avoid sampling bias. The boxed figures represent the level of specific virulences on test seedlings containing the corresponding resistance (assuming that the specific virulence frequency is 100% in these isolates). In both 1976 and 1977, the lowest virulence level was obtained by isolates on test seedlings of Maris Huntsman, which again corroborates other evidence that this variety has additional resistance, as yet undefined.

Omitting the boxed figures and the WMR7 sample group (3 isolates only), WMV1, WMV2, WMV5, WMV8 and WMV9 are seen to be at fairly high frequencies throughout all isolates in both years. However, the only WMR group which shows a fairly high non-corresponding virulence frequency on the majority of test seedlings is WMR2+4. Even so, the scope for suitable varieties to mix for mildew control is limited because so many of the virulences are generally common. Thus a different situation exists from that in the barley mildew system.

Population virulence frequencies

It has been suggested that overall mean frequencies of different virulences might be of some interest from year to year. Table 4 shows the mean virulence frequencies taken for all tested samples in 1976 and 1977. Whilst these figures do give an indication of how a particular virulence may fluctuate, they are heavily dependent on the range and number of varieties sampled in each year and do not give the true 'base' value of the virulence frequency in the population at large. Furthermore, since samples are taken at various times during the season, they neither represent frequencies at one particular point in time nor the accumulated total.

A better estimate of the base virulence frequencies may be obtained by excluding the sample values from varieties with resistance which specifically interacts with the virulence in question, although it is still subject to the temporal criticism mentioned above. These base frequencies for 1976 and 1977 are given in Table 5. The WMR2 virulence is the only one to have decreased in frequency over the two years. If this decrease is real, it is presumably due to the decline in popularity of WMR2 varieties (e.g. Maris Nimrod). The virulence corresponding to WMR7 appears to have

Table 3. Percentage relative frequencies of virulences from each of the WMR groups in 1976 and 1977

WMR Group	Year	WMV Group 1	2	4	5	7	8	9	2+4	2+6[1]	2+6[2]	5+8	2+4+6[3]	2+4+6[4]
0	1976	46	71	5	23	9	41	25	3	7	1	-	-	-
	1977	74	65	6	57	1	59	34	5	16	2	37	3	3
2	1976	63	88	43	0	0	23	76	19	0	0	-	-	-
	1977	95	137	37	21	1	36	93	34	15	3	7	14	17
7	1976	<1	0	1	0	116	30	0	0	0	0	-	-	-
	1977	135	2	0	0	143	0	0	0	0	0	0	0	0
8	1976	59	66	15	45	4	70	26	15	15	11	-	-	-
	1977	86	82	30	80	0	88	28	37	9	0	53	11	4
2+4	1976	88	100	113	29	22	50	84	106	3	1	-	-	-
	1977	132	157	174	46	1	43	106	117	18	10	46	35	32
2+6	1976	30	71	10	23	3	40	15	0	76	65	-	-	-
	1977	58	116	17	27	0	36	38	24	74	43	10	10	19

1, 2, 3, 4: as in Table 2

Table 4. Overall mean percentage virulence frequencies from surveys in 1976 and 1977

Year	WMV Group 1	2	4	5	7	8	9	2+4	2+6[1]	2+6[2]	5+8	2+4+6[3]	2+4+6[4]
1976	47	80	15	24	2	44	32	16	25	19	-	-	-
1977	81	93	22	42	9	54	39	19	34	17	27	7	7

1, 2, 3, 4: as in Table 2

Table 5. Overall mean virulence frequencies omitting those samples from varieties which directly affect the values: 1976 & 1977

Year	WMV Group 1	2	4	5	7	8	9	2+4	2+6[1]	2+6[2]	5+8	2+4+6[3]	2+4+6[4]
1976	47	66	6	23	1	41	29	5	6	2	-	-	-
1977	81	58	12	42	1	52	39	12	15	4	27	7	7

1, 2, 3, 4: as in Table 2

remained relatively rare and static in the general population because there has been virtually no selection for it. One may speculate that the general increase in frequency of the other virulences may be attributable to the somewhat unique meteorological conditions which prevailed during 1976 so that the composition of the overwintering population was altered.

This technique for monitoring virulence frequencies is very inadequate and subject to considerable error. An improved method should be sought if indeed these measurements are of real value. Further criticisms regarding the calculation of individual virulence frequencies are made elsewhere in this report (Wolfe & Wright).

Tumult Multiline

The individual lines and the line mixture were sampled from plots growing at the PBI. The isolate from Line 1 confirmed laboratory observations that this line carries the 1R rye resistance. The absence of this virulence from the mixture isolate suggests that the corresponding resistance may be effective when buffered by other resistances in neighbouring plants. The absence of WMR2 virulence from the mixture sample is curious since four of the component lines supported this virulence. It also gives rise to suspicion of the sampling technique: although mildew from leaves of 25 tillers was bulked, it appears that mildew from line 3 had predominated in the mixture sample (see Table 2). This highlights a severe limitation in the methods used to sample mixtures and multilines.

Polythene Tunnels

Examination of the data by variety groups within geographic locations indicated an unusually high WMR4 virulence frequency in Buckinghamshire (68%) compared with the rest of the country (19%). When the origin of the 9 samples involved was determined, all were found to emanate from tussock plots in a polythene tunnel. Only one of these plots (Sappo) was contributing directly to the virulence frequency. It seems that under these conditions, this virulence at least can compete on non-corresponding varieties in a way that might mislead the observer. Thus for detailed mildew observations on wheat, it is suggested that polythene tunnel results should be treated with caution.

MILDEW OF OATS

E. Jones & I. T. Jones

Welsh Plant Breeding Station, Aberystwyth

Virulence was detected in 1977 to all seedling resistance factors at present available in commercially grown varieties of oats. Although sampling in this year was very restricted, the general trend of the period 1971 - 76 continued in 1977 in that the incidence of the more complex races 3, 4 and 5 has shown an increase, while the previously predominant and relatively simple race 2 has continued to diminish.

A total of only twenty seven samples were received, seven of which failed to culture. Furthermore, samples were received from only two regions probably because of the generally low incidence of mildew during this season. Of the samples which were cultured successfully, thirteen were from the Welsh Plant Breeding Station (W. P. B. S.) or Morfa Mawr (Aberystwyth, Dyfed, Wales), and seven from Headley Hall (Yorks, Eastern Region). Consequently, the following observations should be viewed in the light of this restricted sampling.

However, as in 1976, four races were detected, namely races 2, 3, 4 and 5 (Hayes & Jones, 1966) indicating that all seedling resistance factors available in commercial varieties are overcome.

The most virulent race 5 (attacking both Cc 4146 and 9065 Cn seedling resistance factors), was for the second year in succession one of the most prevalent races (seven samples = 35% of total). Six of these samples were from Morfa Mawr and were mainly from varieties with resistance derived from Cc 4146, namely, Maris Tabard, Maris Oberon, Nelson and Margam. The other sample of race 5 was from Headley Hall from the variety Maris Quest, which has no known genes for resistance, indicating that this virulent race is able to compete satisfactorily with other less complex races.

Race 4, virulent on 9065 Cn and Mostyn (the latter with resistance derived from 9065 Cn) but avirulent on Cc 4146, was also detected in seven samples (35% of total) thus showing a slight increase relative to race 5 compared with 1976 but all the samples came from W. P. B. S. or Morfa Mawr.

Race 3, virulent on Cc 4146 but not on 9065 Cn, was identified in five samples (25% of total) all of which were from Headley Hall. Three of the varieties sampled have resistance derived from Cc 4146, namely, Margam, Nelson and Maris Tabard, while the other two have no known genes for seedling resistance, namely, Peniarth and Maris Osprey.

Race 2 (the simplest of these four races and avirulent on both Cc 4146 and 9065 Cn) was detected on only one sample of Pennal (winter variety) from Headley Hall. This reflected the trend that has been evident since 1971 for the incidence of this race to diminish while races 3, 4 and particularly 5 have shown a marked increase.

Over the past ten years during which the survey has been operating, it appears that the frequency of a particular virulence gene in the oat mildew population is positively associated with the release and subsequent increase of the area sown to varieties with the corresponding seedling resistance gene.

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RHYNCHOSPORIUM OF BARLEY

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

Welsh Plant Breeding Station, Aberystwyth

Of the 119 samples of Rhynchosporium secalis successfully cultured from the 155 received, 40 were identified as race UK 1 and 79 as race UK 2. The variety Magnum was resistant to all isolates. Isolates cultured on plants of Maris Mink, prior to inoculation of the differential varieties, were more pathogenic than they were when cultured on lima bean agar. Different isolates varied in their aggressiveness as measured by the rate and degree of symptom expression on Maris Mink and Triumph and the range of response was similar for both race UK 1 and race UK 2. No isolates were found to be specifically adapted to any winter barley variety when subjected to monocyclic inoculation tests in four different controlled environments but the tests allowed the varieties to be ranked in order of resistance.

MATERIALS AND METHODS

In order to maintain the relevance of the Rhynchosporium surveys and to bring in any necessary modifications, a small discussion group was convened at WPBS in May 1977 before the commencement of sample testing. Dr John Kay (Miln Marsters) was invited to contribute and Dr Janet Rowe(NIAB) was also consulted by correspondence. The outcome of these discussions was a decision to modify the testing procedures by:

1. Expanding the set of differential varieties to consist of

Maris Mink	-	Susceptible check
Triumph	-	Susceptible check
Armelle	-	Resistance Rh. Also in winter varieties
La Mesita	-	Resistance Rh^4. Used by breeders
Magnum	-	Resistance Rh^4? Recommended variety

2. Developing an assessment key which would allow quantitative response to be measured on the same scale. The key used is shown in Table 1.

Table 1. Key to assess response of barley seedlings to Rhynchosporium secalis

Scale	Host response
0	None
1	Single lesions on edge of leaf
2	Continuous lesions on edge of leaf
3	Single complete lesions dispersed along length of leaf
4	Single complete lesions fusing to form larger areas of infection
5	50% of leaf surface area infected
6	60% " " " " "
7	70% " " " " "
8	80% " " " " " Leaf dying due to infection
9	Leaf dying due to infection
10	Leaf dead

In addition, latent period i.e. length of time for symptoms to appear, was also recorded which, together with the symptom type data, allowed an estimate of pathogen aggressiveness to be made.

3. It was also proposed to compare the relative aggressiveness of ten R. secalis isolates following culture either on lima bean agar or on plants of Maris Mink to determine the most meaningful test procedure. All other survey isolates were cultured on Maris Mink.

4. A set of winter varieties was assembled and tested against ten selected isolates of R. secalis under four controlled environments. These were 1) 20°C/16 h photoperiod; 2) 15°C/16 h photoperiod; 3) 15°C/16 h photoperiod, 10°C/8 h dark period, and 4) 5°C/8 h photoperiod.

These tests were to assess resistance of winter varieties and to detect any isolate x variety interactions. The varieties selected were: Maris Otter, Igri, Sonja, Senta, Astrix, Mirra, Hoppel, Maris Trojan and Athene.

RESULTS

The incidence of Rhynchosporium nationally was relatively high in 1977 and this was reflected in the high number of samples received. A total of 155 samples were submitted for testing including 67 from spring varieties, 64 from winters and

24 from breeding lines, volunteer plants etc., and of these, 119 were successfully tested.

Race UK 1 was identified from 40 samples and race UK 2 from 79 samples. Of the 44 isolates cultured from cultivated spring varieties 22 were UK 1 and 22 were UK 2 whereas, on the winter varieties, UK 2 was identified 51 times and UK 1 only nine times reflecting the resistance of 6 - rowed winter varieties to race UK 1. Magnum was resistant to all isolates although 36 of the 79 UK 2 isolates gave a 1 - 2 reaction type. La Mesita was similarly resistant to all isolates but 20 of the 36 race UK 2 isolates which gave the higher response on Magnum also gave 1 - 2 infection types on La Mesita as did 7 race UK 1 isolates. The relative numbers of isolates classified as race UK 1 and UK 2, their distribution and origin on winter or spring varieties is summarised in Table 2.

Table 2. Distribution of *Rhynchosporium secalis* races UK1 and UK2 by region and varietal origin, 1977.

Region	Winter varieties		Spring varieties	
	UK1	UK2	UK1	UK2
Scotland	-	3	4	1
N. Ireland	-	-	1	-
North England	1	-	-	-
East Midlands	-	1	-	-
West Midlands	2	19	3	3
Wales	-	3	-	3
S.W. England	1	20	5	12
South England	1	3	5	1
Eastern England	4	2	4	2
Total	9	51	22	22

The results of infection by the ten selected isolates inoculated onto the differentials following culture on lima bean agar or Maris Mink clearly demonstrated the relative aggressiveness of cultures from host plants compared with those grown on artificial media (Table 3).

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7	70% " " " " "
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East Midlands	-	1	-	-
West Midlands	2	19	3	3
Wales	-	3	-	3
S.W. England	1	20	5	12
South England	1	3	5	1
Eastern England	4	2	4	2
Total	9	51	22	22

The results of infection by the ten selected isolates inoculated onto the differentials following culture on lima bean agar or Maris Mink clearly demonstrated the relative aggressiveness of cultures from host plants compared with those grown on artificial media (Table 3).

Table 3. Infection of barley varieties resulting from inoculum derived from host plants vs artificial media

Inoculum source	Infection* ($\bar{x}$ of 10 isolates)		$\bar{x}$
	Maris Mink	Triumph	
Lima bean agar	5.4	6.8	6.1
Maris Mink	9.0	9.8	9.4

* 0 - 10 scale

In the test to assess the relative aggressiveness of race UK1 and race UK2 as measured by the rate and degree of symptom expression on the susceptible check varieties Maris Mink and Triumph the results obtained for both groups of isolates were similar (Table 4).

Table 4. Percentage of isolates with different levels of infection ($\bar{x}$ of Maris Mink and Triumph)

Infection level (0 - 10 scale)	Isolates	
	UK1	UK2
1	-	0.63
2	-	0.63
3	-	0.63
4	1.25	0.63
5	1.25	4.43
6	3.75	6.33
7	3.75	12.66
8	22.50	29.11
9	33.75	19.22
10	33.75	25.95

Although overall, isolates of UK2 were slightly less aggressive than UK1, the vast majority were highly aggressive under the glasshouse test environment.

Of the ten isolates of race UK2 selected from the survey samples for tests on winter varieties, two each were from Hoppel, Athene and Igri and one each was from Sonja, Katy, Trojan and Astrix. Each isolate was inoculated onto four sets of the nine winter varieties listed above, one set then being placed in each of the four controlled environments.

No specific adaptation was detected to the varieties from which the isolates originated and there were no significant interactions between varieties and isolates. Symptoms developed fastest at the high temperature (mean of 10.14 days to first appearance of symptoms) but the development time was similar for the 15°C regime (10.78 days) and the 15°C/10°C regime (10.93 days). At 5°C symptoms appeared after an average of 17.9 days.

The varieties were ranked for their mean levels of infection over the four environments.

Variety	Infection %
Hoppel	2.4
Senta	4.2
Mirra	5.7
Trojan	6.6
Astrix	7.9
Sonja	8.7
Igri	9.9
Athene	12.2
Otter	25.5

VARIETAL DIVERSIFICATION SCHEMES FOR WHEAT YELLOW RUST AND BARLEY MILDEW

The two following papers were sent to the authorities responsible for evaluating new cereal varieties in England & Wales, Scotland and Northern Ireland, and to the Agricultural Development & Advisory Service.

The schemes update those in the 1976 Annual Report.

VARIETAL DIVERSIFICATION TO REDUCE RISK OF YELLOW RUST IN WINTER WHEAT

The risk of severe yellow rust infections can be reduced by growing a number of varieties each containing a different resistance factor. The effect of this is that if one variety becomes severely infected, it is unlikely that the other varieties will become infected to the same degree.
The winter wheat varieties have been arranged in diversification groups (DG 1 - 7) on the basis of information supplied by the Physiologic Race Survey of Cereal Pathogens.

DG 1	DG 2	DG 4	DG 7
Aquila	Grenade	Mega	Clement
Armada	Hustler		
Atou	Maris Huntsman		
Bouquet	Maris Nimrod	DG 5	
Flanders	Maris Templar	Cappelle-Desprez	
Fleurus	Sportsman	Champlein	
Flinor			
Kador			
Mardler	DG 3	DG 6	
Maris Widgeon	Kinsman	Hobbit	
Valmy	Maris Freeman	Score	
Waggoner	Maris Ranger		

Selection of varieties to grow together

+ = varieties can be grown together
- = varieties should not be grown together

	DG 7	DG 6	DG 5	DG 4	DG 3	DG 2	DG 1
DG 1	+	+	+	+	+	+	+
DG 2	+	+	-	+	+	-	
DG 3	+	+	+	+	-		
DG 4	+	+	+	-			
DG 5	+	+	-				
DG 6	+	-					
DG 7	-						

Spring wheat varieties should not be grown near winter wheat varieties. If this is unavoidable, select spring varieties with a high level of resistance.

VARIETAL DIVERSIFICATION TO REDUCE SPREAD OF MILDEW IN SPRING BARLEY

Levels of mildew can be reduced by growing a number of varieties each containing a different resistance factor. This lessens the likelihood of mildew spreading from variety to variety and thu slows down the epidemic.
The spring barley varieties have been arranged in diversification groups (DG 1 - 7) on the basis of information supplied by the Physiologic Race Survey of Cereal Pathogens.

DG 1
Armelle
Clermont
Freegold
Golden Promise
Imber
Julia
Proctor
Zephyr

DG 2
Midas

DG 3
Abacus
Ambre
Georgie
Lami
Lofa Abed
Mala Abed
Sundance
Varunda
Universe

DG 4
Goldmarker
Jupiter
Minak

DG 5
Aramir
Athos
Hassan
Maris Mink
Porthos
Printa

DG 6
Ark Royal
Dram
Firecrest
Keg
Mazurka
Wing

DG 7
Albion
Magnum
Tyra

Selection of varieties to grow together

\+ = varieties can be grown together
\- = varieties should not be grown together

	DG 7	DG 6	DG 5	DG 4	DG 3	DG 2	DG 1
DG 1	-	-	-	-	-	-	-
DG 2	+	+	+	-	+	-	
DG 3	+	+	+	-	-		
DG 4	+	+	+	-			
DG 5	+	+	-				
DG 6	+	-					
DG 7	+						

Winter barley varieties should bot be grown near spring barley varieties. If this is unavoidable, select winter varieties with a high level of resistance.

VARIETAL DIVERSIFICATION TO REDUCE SPREAD OF MILDEW IN SPRING BARLEY

Levels of mildew can be reduced by growing a number of varieties each containing a different resistance factor. This lessens the likelihood of mildew spreading from variety to variety and thus slows down the epidemic.
The spring barley varieties have been arranged in diversification groups (DG 1 - 7) on the basis of information supplied by the Physiologic Race Survey of Cereal Pathogens.

DG 1
Armelle
Clermont
Freegold
Golden Promise
Imber
Julia
Proctor
Zephyr

DG 2
Midas

DG 3
Abacus
Ambre
Georgie
Lami
Lofa Abed
Mala Abed
Sundance
Varunda
Universe

DG 4
Goldmarker
Jupiter
Minak

DG 5
Aramir
Athos
Hassan
Maris Mink
Porthos
Printa

DG 6
Ark Royal
Dram
Firecrest
Keg
Mazurka
Wing

DG 7
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Magnum
Tyra

Selection of varieties to grow together

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	DG 7	DG 6	DG 5	DG 4	DG 3	DG 2	DG 1
DG 1	-	-	-	-	-	-	-
DG 2	+	+	+	-	+	-	
DG 3	+	+	+	-	-		
DG 4	+	+	+	-			
DG 5	+	+	-				
DG 6	+	-					
DG 7	+						

Winter barley varieties should bot be grown near spring barley varieties. If this is unavoidable, select winter varieties with a high level of resistance.

VARIETAL DIVERSIFICATION TO REDUCE SPREAD OF MILDEW IN SPRING BARLEY

Levels of mildew can be reduced by growing a number of varieties each containing a different resistance factor. This lessens the likelihood of mildew spreading from variety to variety and thu slows down the epidemic.
The spring barley varieties have been arranged in diversification groups (DG 1 - 7) on the basis of information supplied by the Physiologic Race Survey of Cereal Pathogens.

DG 1
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DG 2	+	+	+	-	+	-	
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DG 4	+	+	+	-			
DG 5	+	+	-				
DG 6	+	-					
DG 7	+						

Winter barley varieties should bot be grown near spring barley varieties. If this is unavoidable, select winter varieties with a high level of resistance.