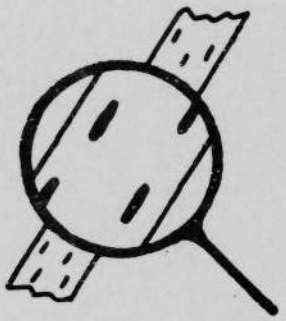
U.K. CEREAL PATHOGEN VIRULENCE SURVEY



1978 Annual Report

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UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

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THE UNITED KINGDOM CEREAL PATHOGEN VIRULENCE SURVEY

The Survey, formerly the Physiologic Race Survey of Cereal Pathogens, commenced in 1967 following an unexpected epidemic of wheat yellow rust (*Puccinia striiformis*) 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 monitoring the frequency of virulences and virulence combinations, evaluating the compatibility of virulences with one another, measuring the effect of changes in variety on the pathogen population and providing information for varietal diversification schemes.

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 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 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'.

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.

MILDEW OF WHEAT

Fiona G.A. Bennett
Plant Breeding Institute, Cambridge

Cultivars relevant to commercial agriculture were assigned to appropriate Wheat Mildew Resistance (WMR) groups. Differential test cultivars were brought up to date as far as possible.

Mildew was not generally severe in 1978. Considerable loss of samples was sustained through unfortunate postage and packing arrangements.

Virulence frequency analysis indicated the problem of plot-to-plot interference in disease sampling. The general structure of sample populations was similar to that observed in 1977. Virulence frequencies in the overall population, however, showed some marked changes. Notably, the WMV2+6 combination doubled in frequency.

The interaction between WMV2+6 and the corresponding resistance combination was evaluated. Mobile nursery data showed that WMV2+6 could increase in frequency where selection pressure was strong enough to overcome the competitive disadvantage of WMV2+6. Since WMR2+6 cultivars are likely to become more common, adaptation of the winter wheat diversification scheme to accommodate the increased risk of mildew epidemics was suggested.

RESISTANCE GROUPS

In previous years (1976 and 1977) it was possible to monitor the frequencies of several virulences which did not correspond to resistances widely used in agriculture because the majority of cultivars being grown had no identified resistance genes. This situation no longer exists

(see Table 6a) and it was therefore considered that only virulences currently or potentially important in agriculture should be studied. Thus Wheat Mildew Resistance (WMR) group 3 has been omitted from Table 1, in which the WMR groups are set out. Cultivars relevant to agriculture have been assigned to appropriate WMR groups.

Table 1. Differential cultivar (underlined) and other cultivars assigned to their appropriate Wheat Mildew Resistance (WMR) groups with identified resistance genes where known

WMR Group	Gene	Cultivars
0	-	Hobbit, Atou, Maris Freeman, Bouquet, Flinor, Iona, Champlein, Maris Ranger
1	Pm1	Anfield
2	Pm2	Sportsman, Maris Nimrod, Wizard, Sentry*, Bounty*
4	Pm4b	Weihenstephan M1, Cardinal, TW256*
5	Pm5	Hope, Redcoat
6	Pm6	Timgalen, Mengavi
7	Pm8	Salzmünde 14/44, Clement, Nautica, Stuart*
8	?	Flanders, Mega, Waggoner, Aquila*
9	Pm2+'M1d'	Maris Dove
2+4		Sappo, Armada
2+6		Maris Huntsman, Kinsman, Mardler, Hustler, Brigand*, Virtue*, Marksman*
5+8+?		Sicco
2+4+6		Timmo, Walter

*Cultivar added to group since 1977

WMR group number bears no relationship to the number of the particular Pm gene or genes concerned. The sources of resistance where known were given by Bennett (1978, Table 1).

Whilst some cultivars have been added to various groups (those marked with an asterisk), no new resistance genes or combinations have been identified. It seems, however, that the WMR group for which Sicco is used as a differential (5+8+?) is more complex than originally thought: several isolates received in 1978 were virulent on Hope and Flanders but not on Sicco. Therefore Sicco most probably has additional unidentified resistance.

A number of cultivars have proved difficult to assign to WMR groups. These include Kador, Highbury, Spartacus and Arminda.

DISEASE INCIDENCE AND SAMPLES RECEIVED

The overall mean figure of 1.03 per cent mildew on Leaf 2 obtained by the Plant Pathology Laboratory Survey reflected the generally low incidence of powdery mildew on wheat in 1978. This figure, however, concealed individually severe cases which occurred in certain areas, and ignored low incidence due to resistant cultivars, which are becoming more popular.

The fate of samples received is given in Table 2.

Table 2. Fate of wheat mildew samples received in 1978

Source variety	Number of samples	Failed to establish	Died in culture	Satisfactorily tested
Flanders	15	3	2	6
Hobbit	13	3	2	4
Maris Huntsman	11	5	3	0
Aquila	6	2	0	1
Stuart	6	1	0	4
Waggoner	6	2	0	4
Iona	5	1	0	2
Kador	5	1	0	3
Armada	4	1	0	1
Wizard	4	0	1	1
Arminda	3	1	0	0
Sicco	3	3	0	0
Highbury	2	2	0	0
Spartacus	1	0	0	0
Timmo	1	1	0	0
Others	38	1	6	14
Total	123	28	14	40

Eighty-five samples were sent from cultivars included in the request list sent out in April 1978. The highest proportion of isolates lost prior to testing occurred in samples taken from Maris Huntsman. The three remaining Huntsman isolates have not yet been satisfactorily tested owing to general lack of vigour.

In 1978 colony numbers were counted automatically using a New Brunswick Biotran II Automatic Colony Counter. The testing procedure used was basically unchanged only scores were obtained more rapidly and with greater repeatability.

VIRULENCE FREQUENCY ANALYSIS

As in previous years, the samples were inoculated as bulk isolates to a set of differential cultivars and the frequencies assessed as colony numbers. In the tables these frequencies have been expressed as percentage relative frequencies, the number of colonies on Hobbit (the WMRO differential) being taken as 100 per cent in each test. Table 3 shows the reactions of 40 bulk isolates on seedlings of relevant test cultivars.

Analysis of isolates showed, in general, similar trends to 1977. Samples taken from WMRO cultivars suggested a particular difference between the two years: some of the more common virulences occurred at lower frequencies in 1978 and were absent from a greater proportion of these samples. This may be the result of selection against unnecessary virulence in the pathogen population.

Assessment of virulence WMV6 in the population was possible due to the inclusion of Timgalen as a differential cultivar (Table 1). This virulence was present in 35 per cent of the samples analysed. Although WMV2 was also present in every case, the two virulences were apparently combined in only six out of the thirteen samples (Table 6b).

One isolate taken from an advanced spring wheat breeding line, TW256, suggested that this line belonged to WMR4, as does one of its parents, ELS. The corresponding virulence WMV4 is known to respond rapidly to selection, which might jeopardise this variety's mildew resistance. Several isolates from less common cultivars, namely Carstens V, Nugaines, Suwon 92, Michigan Amber and S 112 were sent from Ireland; it was notable that in every case WMV4 was also at a high frequency, as was the combination WMV2+4. It is unlikely that all these cultivars possess the corresponding resistance genes: presumably these unusually high frequencies reflect plot-to-plot interference and were due to the presence of WMR4 and WMR2+4 resistance in the trials.

The effect of plot interference can be seen by examining the results for the four samples taken from different plots of the spreader cultivar Cerco located at various points in a PBI observation trial. For example,

Table 3. Percentage relative virulence frequencies in bulk isolates received in 1978

WMR Group	Source Cultivar	Percentage virulence frequencies relative to Hobbit Wheat Mildew Virulence (WMV) Group												Number of Virulent Isolates
		1	2	4	5	6	7	8	9	2+4	2+6	5+8+?	2+4+6	
0	Hobbit	8	56	18	4	13	24	34	28	0	15	5	0	4
	Minister	49	62	0	0	15	0	0	0	3	28	0	0	2
	Ranger	0	66	6	64	0	0	67	0	0	0	0	0	1
	Iona	0	27	61	11	0	0	43	57	0	0	0	0	2
	Little Joss	0	48	0	27	0	0	48	0	0	0	8	0	1
2	Wizard	191	45	0	109	6	0	118	0	0	0	93	0	1
4	TW 256	121	84	106	76	29	0	100	92	88	54	71	62	1
7	Stuart	6	6	0	12	1	104	29	0	0	0	2	0	4
8	Flanders	61	71	0	54	16	0	90	25	0	15	29	0	6
	Waggoner	108	51	0	71	28	1	56	47	0	26	77	10	4
	Aquila	0	95	0	2	0	0	64	0	0	0	0	0	1
2+6	CI 12633	41	126	0	4	70	0	5	0	0	105	0	0	1
?	Kador	32	58	28	2	0	0	8	48	23	0	1	0	3
	Carstens V	119	32	50	94	25	153	99	61	87	0	87	0	1
	Nugaines	145	41	97	0	0	0	0	53	117	0	0	26	1
	Suwon 92	79	104	118	85	0	0	72	98	132	0	83	0	1
	Michigan Amber	107	67	98	72	20	0	82	56	66	5	37	4	1
	S 112	120	103	128	0	0	0	13	103	133	0	0	0	1
-	Cerco 1	70	11	0	0	0	0	9	0	0	0	0	0	1
	Cerco 2	9	56	0	0	0	0	8	15	0	0	0	0	1
	Cerco 3	63	0	0	0	0	0	41	0	0	0	0	0	1
	Cerco 4	13	83	0	45	11	0	88	0	2	0	0	0	1

samples 2 and 3 from Cerco suggest differential adaptation in respect of WMV1 and 2. Since Cerco is highly susceptible and allows many different mildew genotypes to grow on it, this may just be a sampling effect. The complete absence of WMV2 from sample 3, however, suggests that a more likely explanation is plot-to-plot interference. In either case, the results emphasize the need for adequate sampling, especially from those cultivars with no clearly demonstrable seedling resistance.

Further information was sought on the mildew populations selected by spring wheat cultivars. Spring wheat seedlings were exposed in field crops and the 25 samples trapped on these seedlings were analysed. Table 4 summarises this data. Whilst the populations selected on Highbury and RPB 13/72 did not provide any further information on the resistance contained in these varieties, there was an indication that Kleiber and Kolibri belong to WMR groups 1 and 2+8 respectively. This has not yet been confirmed experimentally. Similarly it is not known whether Spartacus should be included in WMR8, as is suggested by the data. Predictably, Timgalen selected a high frequency of WMV6 and coincidentally of WMV 2+6.

MONITORING FREQUENCIES OF VIRULENCE IN THE POPULATION

Once again estimates of the base virulence frequencies in the general population were obtained (Table 5) by excluding the sample values from cultivars with resistance that specifically interacts with the virulence in question as explained by Bennett (1978). The Irish isolates mentioned above were also excluded from these calculations since they were obviously biased.

Bearing in mind the limitations involved in attempting to estimate population virulence frequencies (Bennett, 1978; Wolfe and Wright, 1978), several trends seem to be emerging (Table 5). WMV2 appears to be steadily declining as WMR2 cultivars become less commonly grown, even though it is still the most frequent of those virulences being monitored. In contrast, WMV4 and 7 seem to be maintaining steady low frequencies. The sudden decrease in the WMV5+8+? combination cannot be related to any particular fluctuations in cultivar popularity; non-randomness of sampling is therefore the most likely cause. The most notable feature in Table 5 is the annual doubling of the WMV2+6 combination frequency. This is discussed in more detail below.

Table 4. Analysis of isolates selected on seedlings of various spring wheat cultivars exposed in field crops of Hobbit, Bouquet, Sicco, Flanders and others

Seedling cultivar used to obtain isolates	Percentage virulence frequencies relative to Hobbit Wheat Mildew Virulence (WMV) Group												Number of virulent isolates
	1	2	4	5	6	7	8	9	2+4	2+6	5+8+?	2+4+6	
Highbury	37	49	13	13	5	9	47	12	19	0	21	0	5
RPB 13/72	14	9	13	26	34	0	37	0	3	12	9	0	6
Kleiber	100	79	0	17	2	0	46	38	0	2	43	0	2
Kolibri	60	139	0	34	0	0	100	5	8	0	51	1	2
Spartacus	33	42	0	77	3	0	104	0	0	3	29	0	3
Timgalen	42	108	0	47	111	3	68	49	0	132	44	11	2
Walter	78	75	84	0	37	0	0	99	34	96	0	59	1

Table 5. Overall mean percentage virulence frequencies from surveys 1976-1978

Year	WMV Group												
	1	2	4	5	6	7	8	9	2+4	2+6	5+8+?	2+4+6	
1976	47	66	6	23	-	1	41	29	5	2	-	-	
1977	81	58	12	42	-	1	52	39	12	4	27	7	
1978	45	49	8	29	10	3	35	25	2	10	8	1	

EVALUATION OF THE INTERACTION BETWEEN THE WMR2+6 RESISTANCE COMBINATION AND THE CORRESPONDING VIRULENCE

The increasing proportion of winter wheat cultivars in the WMR2+6 group recommended by the NIAB (Table 6a) suggests that these varieties will soon occupy a large acreage in the U.K.

Table 6a. Percentage of winter wheat cultivars in different WMR groups on NIAB recommended list 1976-1979

Year	WMR Group					
	0	2	8	2+4	?	2+6
1976	60	7	13	-	-	20
1977	53	13	13	-	8	13
1978	46	7	7	7	6	27
1979	31	6	13	6	6	38

Table 6b. Comparison of expected and observed frequencies of the WMV2+5 combination in each of 13 isolates collected in 1978

Isolate Number	Source Cultivar	Percentage virulence frequencies			
		WMV2 Observed	WMV6 Observed	WMV2+6 Expected	WMV2+6 Observed
157	Flanders	85	4	3	0
197	Wizard	45	6	3	0
3	Carstens V	32	25	8	0
124	Cerco	83	11	9	0
78	Flanders	139	8	11	0
7	Michigan Amber	67	20	13	5
83	Minister	69	30	21	56
144	TW256	84	29	24	54
101	Waggoner	102	36	37	0
175	Hobbit	94	51	48	60
39	Flanders	92	81	75	87
73	Waggoner	100	75	75	105
99	CI12633	126	70	88	105

Previously the majority of recommended cultivars belonged to WMR0 and therefore contained no identified resistance genes, but nevertheless differed widely in genetic background; now the majority of cultivars do contain identified resistance genes and come from a much narrower genetic background. This increasing use of race-specific resistance, particularly of the WMR2+6 combination, inevitably must increase selection pressure on

the pathogen population to adapt, and may well create the risk of an epidemic.

Further evidence that the risk of epidemics may be increasing comes from an evaluation of the compatability of the virulences corresponding to WMR2 and WMR6. In Table 6b, the observed percentage frequency of the WMV2+6 combination is compared, for each of 13 bulk isolates, with the frequency expected, calculated from the frequencies of WMV2 and WMV6 virulences separately (Wolfe et al., 1976). In general, when either of the component virulences was at a low frequency, the combination usually failed to be detected. When both components were fairly common, however, the observed frequency exceeded the expected, indicating that these virulences were highly compatible in certain circumstances, and that there may even have been some selective advantage in the combination. The knowledge that this virulence combination is increasing in frequency in the general population (Table 5) at an apparently exponential rate supports this idea.

One cultivar in WMR2+6, Maris Huntsman, has remained reasonably resistant despite being grown on a large acreage for several years. Experimental work suggests that this cultivar is not typical of the group (Bennett and Wolfe, 1979) and mobile nursery data obtained in 1978 supports this view. Pots containing healthy seedlings of several WMR2+6 cultivars and control cultivars were exposed in field crops at Balsham, Cambs., and near a drilled winter wheat trial at the PBI, both early and late in the season. The colony numbers developing on the first seedling leaves are given in Table 7. Hobbit was included as a control for the effect of date of exposure.

In most cases, except at the PBI trial location, colony numbers were reduced later in the season on all WMR2+6 cultivars indicating that isolates carrying WMV2+6 were not competing successfully in the population. Brigand alone sustained an increased infection later in the season at two out of the three Balsham locations. Thus, on this cultivar, it was possible for the WMV2+6 combination, in spite of a competitive disadvantage, and even in the absence of any strong positive selection pressure, to increase in frequency. At the PBI, however, where strong selection pressure for the corresponding virulence combination already existed, an increased infection was obtained on all cultivars except Maris Huntsman and Virtue at the end of the season. This demonstrates that, where selection pressure is strong enough, the competitive disadvantage of

WMV2+6 isolates may be easily outweighed by the ability of these isolates to grow where others cannot. Only the resistance of Maris Huntsman and possibly Virtue is strong enough to withstand this effect.

Table 7. Numbers of colonies developing on test seedlings relative to those on the susceptible control cultivar, Minister (100), when pots were exposed in various crops early and late in the season

Test seedling cultivar	Balsham						PBI	
	Bouquet		Flanders		Sicco		Drilled trial	
	11 May	30 June	15 May	30 June	11 May	25 July	4 May	19 July
WMR2+6:								
Maris Huntsman	25	7	34	10	62	0	23	15
Mardler	49	2	20	5	71	0	21	41
Hustler	60	30	15	19	57	51	44	119
Kinsman	41	42	20	15	38	23	39	105
Brigand	58	64	22	8	27	39	57	212
Virtue	39	17	4	15	62	14	47	24
Marksman	47	18	21	22	26	0	31	85
WMR0:								
Hobbit	55	69	110	106	94	97	79	790

Selection pressure for WMV2+6 is only likely to increase (Table 6a) in the near future and it has been shown that the component virulences can be strongly compatible (Table 6b). In addition the overall frequency of WMV2+6 is increasing in the mildew population (Table 5). Some consideration ought therefore to be given to the incorporation of mildew resistance into future winter wheat diversification schemes.

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YELLOW RUST OF WHEAT

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The results of seedling tests indicate that the U.K. population of Puccinia striiformis has reached an equilibrium position relative to the overall resistances R 1 - 10. The results of adult plant tests showed that isolates possessing virulence for Hobbit (R 14) also possess virulence for either Maris Beacon (R 4) or Maris Templar (R 1). The evolutionary significance of this and its implications for the widely grown cultivar Maris Huntsman are discussed. A multi-variate analysis of the results of the adult plant tests is presented and has been used to augment the traditional methods of identifying specific resistances and virulences. Possible further uses of the cultivar and isolate dendrograms 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. If increased virulence is not found after a certain time, it is an indication that the resistance may be of a durable nature.

Methods of detecting increased virulence and the current UK detection system have been described by Priestley (1978). Table 1 shows the specific resistances (R 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 (V) in the UK population of P. striiformis.

VIRULENCE TEST METHODS

Seedling tests with 1978 isolates

A total of 168 disease samples was received by post. This is the largest number received since 1975 and reflects the widespread distribution of the disease in 1978. Samples were collected in a non-random way from Hobbit (31 samples), Kinsman (16), Waggoner (16), Maris Huntsman (12), Kador (9), Armada (5), Score (5), Virtue (5) and 36 other cultivars. The number of samples received from Hobbit exceeded those from Maris Huntsman, in contrast to previous

Table 1. Resistance factors to P. striiformis

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 resistances are effective at all growth stages, adult plant resistances are ineffective at seedling growth stages.

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years, indicating the more widespread occurrence of P. striiformis in Hobbit crops.

Isolates were made from 136 samples; the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Sappo. Fifty-eight isolates were lost due to the failure of the controlled environment equipment in which virulence tests are carried out.

Virulence tests were carried out on 78 isolates to identify virulences compatible with the overall resistances R 1 - R 10. Twelve isolates were found to be mixtures and have been excluded from the virulence frequency calculations.

Adult plant tests with 1977 and control isolates

Virulences compatible with both overall and adult plant resistances were identified in 24 isolates and an isolate mixture using the Polythene tunnel technique described by Priestley & Byford (1978). Tussocks of 36 cultivars were sown on 7-8 November 1977, inoculated on 7 and 30 March 1978, and assessed for percentage leaf area infection using the International Scale (Doling, 1967) on 2 May (GS 31), 16 May (GS 37-39), 31 May (GS 45-58) and 13 June (GS 60-71). The isolates comprised seven controls of known virulence, ten collected in 1977 from plants with a greater than expected disease level, seven from various

inoculated plots, and a mixture of 24 other 1977 isolates (Table 2). Plants in two tunnels were inoculated with isolate 76/71 to measure between-tunnel variation.

VIRULENCE TEST RESULTS

Seedling tests

Sampling was not carried out on a random basis and thus the virulence frequencies shown for 1976-78 (Table 3) should be interpreted with caution. Comparable data for the period 1970-75 was given by Priestley & Byford (1976). Taken together, the data indicate that the UK population of P. striiformis has reached a stable equilibrium position relative to the overall resistances R 1 - 10. The frequencies of V 2 and V 3 have remained at more than 90% in every year since 1971 rendering R 2 and R 3 virtually ineffective. The frequencies of V 5, V 7, V 8, V 9 and V 10 have remained at less than 10%. This may be because cultivars possessing any of the corresponding resistances have not been widely grown in the UK. The frequencies of V 1 and V 4 are closely related to each other, as described by Priestley & Byford (1977). In each of the last eight years, the sum of V 1 + V 4 has been within the range 91 - 104% frequency even though the individual frequencies of V 1 and V 4 have fluctuated widely. This could be due to V 1 and V 4 being allelic but the fact that a few isolates have been found possessing combined V 1,4 suggests that this is not the case. The two loci may be linked in repulsion, having a similar mapping distance on different chromosomes (personal communication, R Johnson). The frequency of V 6 has fluctuated widely since 1970 but does not appear to be related to any other individual virulence.

Adult plant tests

The results of the adult plant tests are given (Table 4). Values are mean percent leaf area infection calculated from two replicate tussocks assessed on four occasions. The resistance factors thought to be possessed by each cultivar are shown; the overall resistances (R 1 - R 10) have been determined from seedling test results which are available on request from NIAB and the adult plant resistances (R 11 - R 14) have been determined from the Table. Diversification group (DG) numbers are given for each cultivar. The use of diversification to reduce the risk of severe field infections of P. striiformis has been proposed by Priestley & Wolfe (1977). The boxes in Table 4 enable parts of the matrix to be identified for comment in the text. Values within boxes have no particular numerical or statistical significance.

Table 2. Isolates used in adult plant tests

Code	Cultivar	Region/	Site	V factors*
Control isolates				
71/493	Capta	Sc	Duns	V 1,2,3,7
72/415	Maris Ranger	Sc	East Lothian	V 1,2,3,6
72/852	Maris Ranger	EM	Market Harborough	V (2),3,4,6
74/62	Maris Huntsman	YL	Garton-on-the-Wolds	V 1,2,3
75/109	Kinsman	WM	Harper Adams	V (1),2,3,4,6
76/15	Clement	EM	Boston	V 2,3,4,8,9
76/71	Grenade	Sc	Mains of Ravensby	V 1,2,3
1977 isolates				
77/3	Kinsman	E	Trumpington	V 1,2,3,6
77/4	Hobbit	E	Fulbourn	V (1),2,3,4
77/20	Maris Ranger	E	PBI trial ground	V 1,2,3,(4),6
77/21	Hustler	E	PBI trial ground	V 1,2,3
77/23	Kador	SE	Watlington**	V 2,3,4
77/24	Hobbit	EM	Holbeach	V 1,2,3,(6)
77/26	Hobbit	EM	Tydd St Mary	V 1,2,3
77/30	Lely	EM	Howsham	V 1,2,3,(7)
77/31	Cebeco 186	EM	Howsham	V 1,2,3,(4),(7),(9)
77/36	Hustler	E	Terrington	V 1,2,3
Other isolates				
PBI 75/27	Hobbit inoculated with WYR 72/23			V (1),2,3,4
631	Selection from WYR 74/16 ex Maris Templar			V 1,(2),3,4,6
75/A1	Clement inoculated with 74/62			V (1),2,3,4,(6),9
77/A5	Hustler inoculated with isolate mixture			V 1,2,3
77/A6	Sportsman inoculated with isolate mixture			V 1,2,3
77/A7	Armada inoculated with isolate mixture			V (1),2,3,4,8,9
77/A11	Valmy inoculated with PBI 75/27			V 2,3,4,(9)
mix	mixture of 24 1977 isolates			

( ) partially virulent on corresponding resistance

* virulences compatible with overall resistances (R 1 - 10) shown only (see Table 1).

** isolate WYR 72/23 had been previously inoculated at this site

/ Sc, Scotland; EM, East Midlands; YL, Yorks & Lancs; WM, West Midlands; E, East; SE, South East.

Table 3. Virulence factor frequency (%)

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

None of the 1977 isolates produced greater infection levels on Maris Huntsman and other cultivars possessing R 13 than the control isolates 74/62 and 76/71 indicating no further increase in virulence compared with previous years (box A).

Three of the four cultivars possessing R 13 also possess at least one overall resistance, the exception being Copain. Isolates virulent on R 13 are also slightly virulent on Sportsman and Mardler.

Isolates virulent on Hobbit, Brigand and Maris Bilbo appear to be of two types. The first type all derive from WYR 72/23 found on the PBI trial ground in 1972 and in addition to virulence for Hobbit, Brigand and Maris Bilbo (box B) also possess virulence for Kador and Wizard (box D) and Maris Beacon (R 4) but not Maris Templar (R 1). These isolates probably possess V 2,3,4,14. The second type (box C) originate from commercial crops of Hobbit in East Anglia. They lack virulence for Wizard and Maris Beacon but possess virulence for Maris Templar and probably possess V 1,2,3,14. Isolates of the second type may be an important evolutionary step towards the possible development of combined virulence for Hobbit, Maris Templar and Maris Huntsman ie V 1,2,13,14. Such a development would render diversification between groups DG 2 and DG 6 relatively ineffective and would have important consequences for the widely grown cultivars Hobbit and Maris Huntsman. If adult plant tests carried out in 1979 confirm that isolates virulent on Hobbit are also virulent on Brigand, it may be necessary to remove Brigand from DG 1 and place it in DG 6.

Table 4. Results of adult plant tests

Values are mean percent leaf area infection.
Boxes are for convenience only and have no statistical significance.

Cultivar	R factors	isolate: mix	631	77/ 4	77/ 3	77/ 31	77/ 36	77/ 21	72/ 415	77/ 30	71/ 493	77/ 26	77/ 24	75/ A1	76/ 15	72/ 852	75/ 109	77/ 2
Maris Huntsman	R 2,13	5	3	0	1	1	4	6	2	5	4	1	3	7	1	1	5	1
Hustler	R 1,2,13	2	3	0	0	0	2	8	1	5	2	3	2	2	0	2	4	2
Copain	R 13	7	3	0	0	0	1	7	6	3	1	2	0	2	0	1	7	0
Virtue	R 1,13	7	3	0	2	6	3	6	6	7	7	6	5	5	1	7	6	6
Maris Templar	R 1,13-	5	3	0	6	12	14	10	7	18	18	12	14	6	2	5	7	17
Atou	R var	2	1	1	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Flinor	R 0	3	2	0	0	0	0	0	1	2	2	1	1	1	0	1	1	0
Aquila	R 2	2	2	0	0	0	1	0	0	1	0	1	1	1	1	0	0	0
Iona	R 1,4	5	4	0	0	0	0	0	0	0	1	1	0	0	0	0	1	0
Valmy	R 0	3	2	0	1	0	0	0	1	1	1	2	4	1	0	3	1	0
Sentry	R 4	2	3	0	0	0	0	0	0	0	0	1	0	1	1	4	0	0
Bouquet	R var	4	2	0	0	0	0	1	2	2	3	3	2	1	0	1	3	1
Anvil	R 0	3	2	0	1	0	1	1	0	2	2	6	4	0	2	1	2	0
Flanders	R 1	2	2	0	1	1	2	1	3	4	1	2	2	0	1	3	3	1
Bounty	R 1	6	3	0	0	0	0	1	0	1	1	2	1	0	0	0	0	0
Mega	R var,12	2	2	0	0	0	1	0	2	2	2	2	2	0	3	16	1	1
Armada	R var,12	2	2	0	0	0	0	0	0	1	1	0	0	3	4	17 E	0	0
Sportsman	R 1	4	2	0	0	0	1	4	1	2	2	2	1	1	0	0	0	0
Mardler	R 1,2	10	3	0	0	1	0	4	3	2	1	3	1	0	0	1	0	0
Kador	R 14	3	0	0	0	4	1	3	4	1	2	4	9	1	0	3	2	1
Wizard	R 4,14	2	3	0	0	0	0	0	0	0	0	1	1	3	3	6	4	1
Maris Freeman	R 6+	2	0	0	4	3	0	0	10	1	2	1	0	3	1	12	8	8
Maris Ranger	R 6+	4	3	0	4	3	0	0	10 H	0	2	1	1	5	1	6 G	10	15
Kinsman	R 6	5	1	0	2	2	0	0	7	1	0	2	1	4	0	2	23	8
Tommy	R 7	1	3	0	4	0	1	0	2	23	25	0	0	4	0	2	2	0
Fleurus	R 12	2	2	0	2	3	6	6	7	8	8	3	5	6	3	24	12	12
Waggoner	R 12	7	4	1	6	1	8	1	6	10	5	4	8	10	3	21 F	11	5
Cappelle-Desprez	R 0	5	2	1	5	9	7	8	9	11	10	4	5	3	2	13	10	16
Rothwell Perdix	R 1	6	2	3	10	2	11	9	12	16	11	9	6	7	0	3	14	4
Michigan Amber	R 0	17	8	3	22	18	13	22	14	17	14	13	16	20	24	23	27	25
Joss Cambier	R 11	9	2	2	19	20	21	23	15	32	33	8	19	21	16	5	41	32
Hobbit	R 14	2	1	0	1	1	2	1	1	1	2	18	13	2	0	3	1	0
Brigand	R 14	10	3	0	1	2	2	1	5	7	3	24 C	12	3	2	2	6	4
Maris Bilbo	R 14	2	7	4	10	18	6	11	13	11	9	33	28	13	9	18	18	19
Maris Beacon	R 4	2	1	1	1	2	0	0	1	0	2	0	0	17	15	0	32	24
Clement	R 9	25	0	3	4	0	0	0	5	1	3	0	2	32	43	3	0	0
LSD (P = 0.05)		6	4	2	5	7	5	6	5	6	7	5	6	6	6	7	7	7

DG = Diversification Group

76/ 71	76/ 71	74/ 62	77/ A6	77/ A5	77/ A7	77/ A11	77/ 23	75/ 27	DG
16	14	20	13	14	16	3	3	7	2
17	15	17 A	16	14	17	1	1	0	2
15	19	12	9	20	15	4	0	0	2
22	18	20	22	28	22	0	5	2	2
21	24	18	19	14	21	1	2	0	2
0	0	0	1	1	0	0	0	0	1
0	0	1	1	1	0	1	1	0	1
3	0	0	1	0	3	1	2	0	1
0	0	0	0	1	0	1	0	0	1
0	1	0	1	2	0	3	2	2	1
0	0	1	0	0	0	5	2	2	1
1	2	1	1	2	1	7	3	5	1
0	2	1	2	1	0	6	5	4	1
2	5	5	1	4	2	1	3	1	1
4	4	4	2	4	4	5	0	0	1
1	2	1	2	1	1	1	1	2	4
0	0	0	0	0	0	1	0	0	1
5	10	7	10	5	5	0	0	0	2
3	6	4	8	10	3	2	1	0	1
0	2	3	3	3	0	8 D	5	10	1
0	0	1	1	1	7	15	11	11	1
0	0	3	0	1	1	0	0	0	3
0	1	4	0	0	1	1	1	0	3
2	1	2	1	3	0	1	2	0	3
0	0	1	0	0	2	0	0	1	-
8	9	9	3	9	6	20	8	10	1
10	15	5	5	9	10	14	11	22	5
6	10	12	7	21	6	5	4	9	5
10	6	4	10	23	11	0	2	0	-
18	25	30	25	22	26	19	22	26	-
32	33	37	25	36	32	15	25	48	-
1	3	6	3	2	2	15	17	33	6
11	13	10	6	16	3	15 B	19	16	1
14	17	19	16	19	13	30	32	42	-
0	2	6	1	3	25	17	22	25	-
0	0	4	8	6	47	27	1	1	7
8	4	7	9	9	5	10	6	7	

ce, eg Brigand is very similar to
ustler etc. This is a more objective
nces than the 'boxes' shown in Table 4.

& Law, 1975) may remain effective over
hogen variability so that the development
e evolutionary capability of the pathogen.
var residuals is a measure of this
e may be indicative of cultivars whose

an one disease

the dendrogram (Table 5) are very
ps given in Table 4. At present, the
yellow rust data, but in the future this
diseases for which specific resistance
oe to produce a single scheme for wheat
to yellow rust, brown rust and mildew,
tivars.

esistance evaluation programmes

the resistance of cultivars against a
the virulence of the complete pathogen
can be used to select isolates that
another thus increasing the range of
ch cultivar is evaluated.

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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
78/1	Tadorna	V 1,2,3	41 E 136
78/140	Bersee	V 1,2,3	41 E 136
78/156	Caribo	V 1,2,3	41 E 136
78/157	Grana	V 1,2,3	41 E 136
78/161	Cappelle Desprez	V 1,2,3	41 E 136

Fourteen other yellow rust samples were received, but they failed to sporulate after inoculation onto the universally susceptible cultivar Sappo.

BROWN RUST OF WHEAT

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Of the 13 samples received, 10 were successfully cultured on seedlings of a set of differential cultivars. Sterna was resistant to all cultures and its resistance is designated as R7. A number of isolates from the 1977 survey was tested on adult plants grown in isolation nurseries and in Polythene tunnels. Virulence for Clement (R1) and its derivatives, and also for Maris Ranger and Sportsman, was confirmed. Virulence for the adult plant resistance of Aquila was detected.

The Maris Huntsman resistance (R5) is also apparently present in Mardler and Brigand and that of Maris Fundin (R2) also in Maris Bilbo and Maris Templar, but these results require confirmation. The resistance of Hobbit and Wizard, apparently different from any other, is designated R6. Bounty, Hustler and Venture share a resistance of the adult plant type which is unique to these varieties.

One isolate (WBR-77-15) carried virulence for Clement, Aquila, Maris, Huntsman and Sportsman and another (WBR-77-22) combines virulence for Clement, Aquila and Maris Ranger. The adult plant resistance of Kinsman remains effective against all isolates tested to date.

SEEDLING TESTS 1978

Only 13 samples of wheat brown rust (Puccinia recondita) were received in 1978 and of these, 10 were successfully cultured. Six of these were from Maris Huntsman and one each from Aquila, Brigand, Mardler and Manella. A number of the differential cultivars was resistant to all or some of the cultures (see Table 1). Sterna was resistant to all isolates tested and resistance

Table 1. 1978 Brown rust of wheat seedling test results

Differential cultivar	Isolate WBR-78-									
	1	3	4	5	6	7	8	9	10	13
M. Ranger	S	S	S	S	S	S	S	S	S	S
Hobbit	R	R	R	M	R	R	M	M	M	M
Kinsman	S	S	S	S	S	S	S	S	S	S
Sterna	R	R	R	R	R	R	R	R	R	R
Sappo*	M	M	R	M	R	M	R	R	R	R
M. Halberd*	M	M	R	M	M	M	R	M	M	M
Highbury*	S	S	S	M	S	S	S	M	S	S
Aquila	S	S	S	S	S	S	S	S	S	S
Armada	S	S	S	S	S	S	S	S	S	S
Sportsman	S	S	S	S	S	S	S	S	S	S
M. Fundin	R	S	-	M	M	S	R	S	M	S
M. Huntsman	S	S	S	S	S	S	S	S	S	S
Clement	M	M	M	M	M	M	M	R	R	R
Hustler	S	S	S	S	S	S	S	S	S	S
Bounty	S	S	S	S	S	S	S	S	S	S
Anvil	S	S	S	S	S	S	S	S	S	S
Sentry	S	S	S	S	S	S	S	S	S	S
Wizard	M	R	M	M	M	M	R	M	M	R
Copain	S	S	S	S	S	S	S	S	S	S

* = Spring variety

S = Susceptible; M = Mixed; R = Resistant

designation R7 may be allocated to it on the basis of this and previous tests. Hobbit and Wizard responded similarly giving a mixed or resistant reaction to all cultures, whereas Maris Fundin was susceptible to isolates WBR-78-3, -9 and -13. These results suggest that the seedling resistant of Wizard and Hobbit is different from that of Maris Fundin. Clement was resistant (resistance R1) to all cultures although some of these appeared mixed. The spring cultivars Sappo (R3) and Maris Halberd (R4) were resistant to all isolates.

ADULT PLANT TESTS 1978

Race nurseries, either sown in isolation from one another in the field at WPBS, or in Polythene tunnels at NIAB, were used to investigate the adult plant response of various cultivars to a number of isolates of P. recondita in 1978. The procedures used were similar to those described previously (Clifford, Jones and Priestley, 1978). A summary of the results obtained in 5 different nurseries grown at WPBS is given in Table 2 and in Table 3 for those obtained in the 3 nurseries grown at NIAB.

A number of conclusions may be drawn from the results of these adult plant tests and the seedling tests reported above and also carried out at NIAB.

The virulence to Clement (R1) and its relatives such as Forester, Stuart, Magister, Donata and Hedgehog was confirmed and is carried by isolates WBR-77-15 and -22. These isolates are also virulent on Aquila adult plants which suggest that Aquila and Clement may have a resistance factor in common. However, Clement also carries a seedling resistant which Aquila does not possess. Differences in background resistance within this group of varieties were observed with R1 virulent isolates (see Table 2, column 5). Hedgehog is highly susceptible as is Clement, whereas, Aquila, Stuart and Magister are intermediate and Donata shows a moderate to high level of resistance.

The adult plant resistance of Maris Huntsman (R5) is effective against the Clement-virulent isolate WBR-77-22, but isolate WBR-77-15 appears to carry the combined virulence to R1 and R5. The R5 resistance also appears to be present in Mardier and Brigand (see Table 3).

The resistance of Maris Fundin, which is temperature sensitive, also appears to be present in Maris Templar and Maris Bilbo. However, confirmatory tests need to be made on the latter two varieties. The test results reported above suggest that the seedling resistance of Maris Fundin is different from that of Hobbit and these, and the adult plant tests, indicate that Hobbit and Wizard have a common resistance for which the designation R6 is proposed.

Virulence to the adult plant resistance of Maris Ranger was detected in isolates WBR-77-9 and -22, the former isolate also overcoming the resistance of Sportsman. Isolate WBR-77-15 was also virulent on Sportsman (Table 2).

Table 2. WPBS Isolation nurseries 1978

Isolate	77-9 (ex Ranger)			77-14(ex Hobbit)			77-22(ex Aquila)			74-11(ex Fundin)			77-15(ex Sportsman)		
Variety	%*	%‡	RT	%	%	RT	%	%	RT	%	%	RT	%	%	RT
Huntsman	8	11.7	3+	12.3	18.8	3+	4.0	7.0	3+Oc	11.0	16.3	Oc3+	16.9	28.8	3+
Atou	6	9.0	3+	11.6	17.5	3+	7.0	12.5	3+	11.0	15.0	3+	12.3	16.3	3+
Freeman	6.5	9.5	3+	7.1	10.8	3+	5.1	10.0	3+	8.0	13.6	3+	8.0	9.3	3+
Bouquet	7.0	10.3	3+Oc	8.6	15.0	3+	7.5	15.0	3+Oc	11.7	18.8	3+	19.4	31.3	3+
Flinor	8.5	15.0	3+Oc	11.0	17.0	3+	5.5	10.0	3+Oc	10.3	15.0	3+Oc	13.7	25.0	3+
Ranger	6.0	9.0	3+Oc	5.5	8.5	Ocn3	4.6	7.6	Oc3	4.0	4.8	Ocn3	7.1	12.0	Oc3+
Kinsman	4.0	4.5	On3	2.3	4.0	Ocn	2.6	7.5	On3	2.1	3.3	Ocn3	4.3	5.8	Ocn2
Sportsman	6.4	7.6	On3	6.0	8.3	Ocn3	4.0	3.2	On3	4.3	6.5	Ocn3	12.0	25.0	3+Oc
Hobbit	4.6	6.3	On3	3.8	6.0	Oc3	1.8	2.3	On	3.1	3.0	Ocn	4.0	6.0	Ocn3
Aquila	3.5	4.0	Ocn3	3.3	6.3	Oc3	5.3	9.0	3+Oc	8.5	13.7	Ocn3+	13.6	21.3	3+Oc
Forester	1.2	1.5	Oc3	1.8	4.3	Oc3	4.6	8.5	3+Oc	3.8	4.5	Ocn3	18.0	33.8	3+Oc
Mega	7.0	10.0	3+Oc	7.5	12.5	3+	5.7	8.8	3+	7.5	12.5	3+	16.2	23.8	3+
Waggoner	5.0	5.7	3+Oc	5.2	7.5	3+Oc	7.2	11.3	3+	5.4	7.5	Oc3+	14.4	22.5	3+
Armada	9.0	12.0	3+	13.6	21.3	3+	7.1	10.3	3+	15.5	23.3	3+	25.8	40.0	3+
Stuart	3.0	3.7	Oc3	2.1	4.0	Oc3	4.4	7.8	3+Oc	3.3	4.5	Oc3	15.7	25.0	3+Oc
RPB1158/ 73	1.7	2.0	On3	1.6	3.5	Ocn	4.0	7.3	Oc3+	3.0	3.5	On3	10.5	17.0	3+Oc
Magister	2.2	3.3	Oc3	1.8	3.8	Oc3	6.2	10.8	3+	5.0	7.0	Oc3	13.2	20.0	3+Oc
Donata	0.8	1.5	Oc2	0	0	Oi	2.0	2.5	Oc3	3.1	4.5	Oc3	8.2	13.5	On3
Hedgehog	7.6	9.5	On3+	9.0	14.5	On3+	18.1	32.5	3+On	9.6	12.0	On3+	28.0	46.6	3+On

* $\bar{x}$ of last 3 assessments

‡ final assessment

Table 3. NIAB Polythene tunnel tests 1978

Resistance factor	Cultivar	isolate 74/ 2	77/ 9	77/ 22	Mean
R1	Clement	1R/R	18	39	-
	Aquila	1S/R	12	25	-
R2	Maris Bilbo	2S/R	26	13	-
	Maris Templar	3S/R	17	19	-
R5	Maris Huntsman	24	19	7S/R	-
	Mardler	28	20	4S/R	-
	Brigand	34	13	8S/R	-
	Maris Ranger	1S/R	12	12	-
	Sportsman	1S/R	14	3S/R	-
R6	Hobbit	2R/R	3R/R	1R/R	-
	Wizard	8R/R	5R/R	5R/R	-
	Bounty	1S/R	6S/R	3S/R	-
	Hustler	1S/R	0S/R	0S/R	-
	Venture	2S/R	0S/R	1S/R	-
	Fleurus	1	2	2	1.7
	Sentry	12	5	5	7.3
	Cappelle-Desprez	10	5	8	7.7
	Bouquet	14	4	7	8.3
	Iona	12	8	6	8.7
	Flinor	15	7	10	10.7
	Mega	11	12	12	11.7
	Maris Freeman	15	11	12	12.7
	Valmy	16	8	18	14.0
	Atou	18	10	15	14.3
	Flanders	17	11	16	14.7
	Waggoner	11	11	24	15.3
	Kador	22	12	21	18.3
	Anvil	25	18	18	20.3
	Rothwell Perdix	20	27	26	24.3
	Tommy	24	27	25	25.3
	Joss Cambier	29	20	29	26.0
	Maris Beacon	34	26	27	29.0
	Copain	33	31	30	31.3
	Armada	32	34	29	31.7
	Michigan Amber	33	35	36	34.7
	LSD (P = 0.05)	5	8	8	

Values are mean percent leaf area infection from 2 replicate tussocks assessed on 5 dates. Underlined values have significantly (P = 0.05) negative residuals indicating a large negative interaction between cultivar and isolate.

R = resistant reaction, S = susceptible reaction at seedling/adult plant growth stages. Reactions not shown are susceptible at both growth stages.

Another related cultivar, Kinsman, was resistant or moderately resistant to all isolates tested which suggests that it has resistance factors not possessed by Ranger and Sportsman.

The cultivars Bounty, Hustler and Venture were seedling susceptible and adult plant resistant in Polythene tunnels at NIAB (Table 3) and it appears that they possess a common resistance which may be different from any other so far detected.

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MILDEW OF BARLEY

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No new major virulence genes were identified, although several new cultivars were assigned to their appropriate BMR groups. Isolates with specific adaptation to Dram and Triumph were obtained for the first time.

The overall pathogen population structure was similar to that observed in previous years with no significant shifts in mean fitnesses of the pathogen populations on each of the BMR groups.

Quantitative differences in resistance of cultivars in the same BMR group were observed in mobile nursery tests. Evidence for virulence in the pathogen matching some of the host differences was also obtained.

Comparison of the standard CPVS technique for identifying pathogen isolates correlated well with the mobile nursery technique. One exception was with virulence tests with BMR 4 which appears to be temperature sensitive and operates less well in the high temperature inoculation and incubation conditions of the mobile nursery tests than in the lower temperature conditions of the laboratory tests.

A total of 261 samples was received, including 14 from seven winter barley cultivars.

New resistance identifications

Table 1 shows the number of samples received from each cultivar and the appropriate BMR group to which they belong. Cultivars whose resistance was newly identified in 1978-79 are marked with an asterisk. No new resistance genes were identified.

Table 1. BMR group definitions and numbers of samples received in 1978

BMR group	Gene	Cultivar and number of samples
0	-	Golden Promise (5) Hoppel (1) Maris Otter (1)
1	'Mlh' (2 genes)	a) Igri (2) Sonja (5) (41/145 sub-group)
		b) Athene (3) Astrix (1) Gerbel* (-) (37/136+41/145 sub-group)
2	Mlg (2 genes)	Katy (1) Julia (1)
3	Mla6	Midas (14)
4	Mlv (2 genes)	Lofa (1) Varunda (1) Aurea*(1) Ca9265* (1) Guilden* (1)
5	Mlas	Hassan (11) Arabische (1)
6	Mla4/7 (2 genes)	Wing (6) Keg (6) Ark Royal (4) Kite*(1) Hood*(-) Nordal* (-)
7	Mla	Tyra (6) Anta* (3) Pf 3681* (1)
8	Mla4/9 (2 genes)	Simon (5) Welam (4) WR74103* (3) W6542 (1) RPB 230/74* (1) RPB 467-74* (1)
2+4		Sundance (13) Georgie (4) Kura* (2) Havila* (1) RPB 393-73* (1)
2+5		Aramir (12) Athos (7) Piccolo (3) Porthos (1) Melody* (1) Goblin* (-)
2+5+?		Maris Mink (15)
2+6		Mazurka (3) Allegro* (1)
3+4		Goldmarker (13) Minak (10) Jupiter (8) Goldspear (2)
4+6		Claret (3)
4+?		Magnum (9)
6+ (Abl2)		Triumph (1)
6+?		Dram (8)

* new identifications in 1978-79.

Generally, the level of resistance in the majority of R6 cultivars was similar when measured quantitatively in detached leaf tests. The cultivar Hood, however, appeared to be consistently more susceptible than Wing. Isolates collected from Dram and adapted to it were identified for the first time, though the resistance additional to R6 in this cultivar has not yet been identified. Another V6 isolate collected from Triumph had a high level

of virulence for this cultivar which possesses R6 plus the resistance from Ab 12.

Further tests with Vanja did not elucidate the resistance of the cultivar but did reveal more of the complexity involved. This cultivar is near-immune to the majority of UK isolates, but is partially susceptible to some isolates that have, in common, virulence for Weider, HOR 1036 (Mla3), Wing (Mla4/7) and Akka (Mk9). Virulence for Wing appears to be unnecessary but occurs in the majority of UK isolates that are virulent on HOR 1063. This can be deduced from the performance of an Israeli isolate that is highly virulent on Vanja and HOR 1063, but not on Wing. Apart from Wing, the Israeli isolate is virulent on the same cultivars as the UK isolates that are partially virulent on Vanja, but in addition is also virulent on Ricardo (Mla3), Monte Cristo (Mla9+Mla4+ ?) and Lofa Abed (Mlvl, 2). It is thus possible that Vanja possesses a recombination between the Mla3, Mla4 and Mla9 alleles, combined with resistance Mlvl, 2. Even if the resistance of this host is genetically complex (polygenic vertical resistance?) it does not appear likely to provide durable protection against the pathogen.

Tests with a similar range of isolates showed that Magnum also possesses the Vada resistance (Mlvl, 2) combined with Monte Cristo resistance (Mla9+Mla4+?), and possibly another factor different from that in Vanja. The cultivar has so far proved susceptible only to an Israeli isolate.

Resistance in winter barley cultivars

In monocyclic tests with eight different isolates, Maris Otter (RO) consistently allowed development of about twice as many colonies as Hoppel (RO) indicating greater resistance to infection in the latter cultivar. In the field however, the two cultivars are ranked as equally susceptible, so that if there is no differential change in resistance developmentally, then spore production per colony on Hoppel may be greater than that on Maris Otter.

In other quantitative laboratory tests with Athene and a range of cultivars with similarly derived resistance from Weih. 37/136 and 41/145, inoculated with a range of isolates, the consistently higher resistance of Athene was clearly evident. From more precise field tests with mobile nurseries, it was evident that the relative resistance of Athene seedlings (37/136+41/145 resistance) exposed in large plots of Igri and Sonja, both with 41/145 resistance alone, was due partly to the lower frequency of isolates with combined virulence. The increase in infection of Athene seedlings relative to those of Igri and Sonja in a large plot of Athene could not be explained entirely by a higher frequency of isolates

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

BMR group	Source cultivar of isolate	Number of virulent isolates	BMV group as represented by test cultivars*													
			1	2	3	4	5	6	7	8	2+3	2+4	2+5	2+5+?	2+6	3+4
0	Maris Otter	1	52	70	64	8	3	53	0	0	82	2	6	6	52	3
	Golden Promise	5	51	65	36	16	18	21	0	0	18	6	28	24	29	7
1	Astrix	1	36	68	62	13	9	20	0	0	24	2	0	0	27	14
	Athene	3	47	79	7	2	16	52	0	2	2	3	101	33	53	1
	Igri	1	40	87	42	10	62	13	0	0	30	0	51	36	30	3
	Sonja	5	44	87	24	12	39	43	0	0	20	2	36	24	58	2
2	Katy	1	33	88	109	18	1	2	0	6	91	1	4	0	0	5
	Julia	1	29	67	2	2	35	31	0	0	4	0	41	48	41	0
3	Midas	7	58	69	70	15	27	32	2	0	70	10	41	15	34	16
4	Lofa	1	14	60	2	50	31	0	0	0	2	48	64	40	0	0
	Varunda	1	32	58	13	87	3	3	0	0	14	28	0	3	1	3
	Aurea	1	57	57	12	38	34	0	0	0	0	4	8	18	1	6
	Ca9265	1	10	39	3	75	17	0	0	0	1	38	2	0	1	0
5	Hassan	7	46	76	6	9	68	9	0	0	2	1	60	61	5	0
6	Wing	4	46	69	16	10	2	82	0	0	8	2	5	4	64	0
	Ark Royal	3	33	80	12	3	9	97	0	0	18	1	9	10	87	<1
	Keg	5	57	76	5	9	23	92	0	13	6	2	25	19	82	0
	Kite	1	38	66	1	3	41	88	2	0	0	0	11	17	75	0
7	Tyra	5	48	73	19	7	45	18	73	2	14	3	75	36	10	1
	Pf 3681	1	32	73	23	5	25	18	80	9	33	3	42	35	36	0
	Anta	2	36	80	29	1	19	57	50	0	22	1	23	20	94	0

Table 2 (contd.)

8	Simon	2	45	67	0	1	25	91	0	53	0	4	15	25	95	0
	Welam	1	62	68	13	1	9	87	0	66	8	8	0	27	91	0
	WR 74103	2	63	86	0	1	30	105	0	70	0	2	31	21	109	0
	W 6542	1	61	75	0	5	0	87	0	66	0	8	0	0	73	0
	RPB 236/74	1	70	80	15	0	35	68	0	78	30	3	45	28	77	0
	RPB 407/74	1	96	113	18	1	3	76	0	62	24	5	0	1	134	0
2+4	Sundance	6	39	74	39	72	37	1	0	<1	29	45	48	36	1	21
	Georgie	4	39	81	35	65	40	5	0	2	27	55	45	38	5	34
	Koru	2	48	82	16	43	28	4	0	0	7	35	22	11	8	8
	Mavila	1	74	94	26	47	46	0	0	0	20	38	67	46	0	0
2+5	Aramis	7	34	80	11	7	58	19	0	0	5	6	82	57	21	0
	Athos	5	46	84	40	2	62	23	0	0	35	3	100	62	19	2
	Porthos	1	36	78	1	0	59	2	4	0	0	1	72	53	1	2
	Melody	1	20	85	0	0	38	7	0	0	0	0	99	45	10	0
	Piccolo	3	45	87	55	5	59	25	0	0	32	16	103	57	65	0
2+5+?	Maris Mink	9	56	73	13	7	65	25	3	0	14	4	72	58	23	3
2+6	Mazurka	3	60	87	49	4	13	92	0	0	49	4	20	19	87	1
	Allegro	1	39	104	1	0	25	109	0	0	1	3	25	49	66	0
3+4	Goldmarker	8	41	64	65	56	17	3	0	0	42	33	28	12	18	53
	Minak	7	35	59	80	53	15	3	1	0	60	29	28	21	2	40
	Jupiter	6	44	71	78	60	41	3	0	0	55	29	54	24	3	45
	Goldspear	2	79	41	77	59	2	1	0	0	44	22	6	2	0	51
6+AB12	Triumph	1	65	56	44	1	13	91	0	0	55	0	32	45	82	0
6+?	Dram	3	48	73	38	15	23	85	0	0	17	7	17	14	69	0

Table 2 (contd.)

Mixtures	Lofa-Varunda-Aramir	1	52	69	37	31	41	15	0	0	45	42	71	6	51	3
	Lofa-Mink	1	20	83	20	78	57	11	0	0	12	21	42	69	0	7
	Varunda-Mazurka	2	42	73	3	12	30	48	0	0	1	14	31	52	51	1

* BMV group	test varieties
1	37/136, 41/145, Astrix
2	Goldfoil, Zephyr, Julia, Union
3	Concord, Midas
4	Lofa Abed, Vada
5	Sultan, Hassan
6	H.1063, Wing, Tern
7	Tyra, Algerian
8	Akka, Vanja
2+3	Inis
2+4	Abacus
2+5	Aramir
2+5+?	Maris Mink
2+6	Mazurka
3+4	Maris Canon

with combined virulence: it appears that Athene may have a third resistance factor and that matching virulence may be detectable in pathogen populations selected on the cultivar.

Pathogen population structures

In Table 2 are listed the reactions of bulk isolates in completed tests on seedlings of relevant test cultivars. If detailed reactions of any specific isolates are required, please contact the authors. The pattern of reactions is similar to that observed over the past three years.

The mean values for each interaction have been calculated for Table 3 which illustrates the overall structure of the pathogen population for the past four years.

From the values given, and the experimental errors involved, it is not possible to discern any real shifts in population structure during this period. It is thus possible to amalgamate the data from the four years, to produce Table 4, which provides an interpretation of Table 3 in terms of the degree of specific virulence on each BMR group, and the flexibility, or mean fitness, of the pathogen population selected by each R group.

Table 4. Specific virulence and flexibility of the pathogen populations on each of the major BMR groups over four years

BMR Group	Mean virulence on corresponding host	Mean virulence on BMR 1+2	Mean virulence over other BMR groups
1	51	67*	13
2	72	53'	13
3	90	58	10
4	52	36	6
5	79	44	5
6	81	64	5
7	65	54	14
8	61	60	5+
mean	69	54	9

* includes R2 only

' includes R1 only

\+ excludes the related group R6

Table 3. Mean percentage relative frequency of common virulences of the BMR groups for the 4 years, 1975-1978

BMR group	Year	BMV group										
		1	2	3	4	5	6	7	8	2+4	2+5	3+4
1	75	43	83	33	3	10	42	0	-	-	-	-
	76	83	46	22	1	11	32	0	-	-	-	-
	77	34	58	6	0	29	15	5	0	3	61	0
	78	43	82	28	9	30	40	0	1	2	38	3
2	75	34	98	33	1	16	9	0	0	-	-	-
	76	74	54	28	4	22	21	0	0	-	23	-
	77	70	58	8	1	17	34	0	0	0	26	0
	78	31	78	55	10	18	25	0	3	1	23	3
3	75	35	114	159	0	18	14	0	0	-	-	-
	76	46	21	40	5	31	7	0	0	-	5	-
	77	-	-	-	-	-	-	-	-	-	-	-
	78	58	69	70	15	27	32	2	0	10	41	16
4	75	36	37	1	53	21	18	0	0	-	-	-
	76	39	13	35	60	2	2	0	0	-	0	-
	77	36	40	14	33	13	0	3	0	30	8	4
	78	28	53	7	62	23	1	0	0	30	28	2
5	75	25	43	21	6	145	2	0	0	-	-	-
	76	59	35	17	1	63	1	0	0	0	40	-
	77	17	46	0	0	41	13	0	0	2	37	0
	78	46	76	6	9	68	9	0	0	1	60	0
6	75	68	90	16	4	4	101	0	4	-	-	-
	76	73	43	4	3	1	70	0	0	-	2	-
	77	55	55	9	1	12	65	0	0	3	17	0
	78	49	74	10	6	14	89	0	3	2	14	0
7	76	56	48	38	8	12	6	72	-	-	5	-
	77	37	64	22	9	18	5	57	0	2	37	0
	78	43	75	22	5	36	28	66	2	2	49	1
8	77	34	59	3	5	3	54	0	53	1	6	0
	78	63	83	6	1	19	89	0	68	5	17	0
2+4	77	38	70	17	41	11	0	0	0	70	35	6
	78	43	79	33	59	37	2	0	1	46	45	21
2+5	76	53	43	13	6	50	6	0	0	-	43	-
	77	36	73	6	13	44	6	1	1	11	72	0
	78	40	82	28	4	60	20	0	0	6	88	1
3+4	77	37	50	61	38	8	1	0	0	36	19	29
	78	43	62	74	56	22	3	<1	0	30	34	47

Table 4 shows how each of the pathogen populations has high specific virulence for the group of cultivars from which it was obtained, and also for BMR 1 and 2. On the other hand, all populations have a relatively low mean fitness over all other cultivars, particularly for groups 4, 5 and 6. The population from BMR 4 is interesting in that it has the lowest mean fitness over all cultivars. This may help to explain the relative durability of the intermediate resistance of the BMR 4 cultivars, in that the pathogen population selected by these cultivars would appear to have a poor survival rate on the host population as a whole. Of course, if the area occupied by BMR 4 cultivars were to increase significantly, then the mean fitness of the corresponding pathogen population would be higher which might cause a reversal of the observed pattern. Data from tests with cultivars that carry combinations of BMR factors have been omitted from Table 4 for simplicity; it can be seen from Table 3 however, that the populations on these cultivars largely follow the pattern expected from the cultivars which carry the same resistance factors separately.

Data have also been accumulated for several years now from mobile nurseries of appropriate test seedlings exposed in fields of different cultivars in the Cambridge area. Because of the limited numbers of fields and choice of cultivars, it has been possible to collate a comparison of the mobile nursery technique and the standard survey technique for only two cultivar groups, BMR 5 and BMR 6 (Table 5).

Table 5. Comparison of the pathogen population structures identified over four years in the national survey with mobile nursery analyses over the same period in the Cambridge area

	BMV Group							Correlation (excl. BMV 4)
	2	3	4	5	6	7	8	P
BMR 5 CPVS	50	11	4	79	6	0	0	<0.997
Mob. Nurs.	38	13	35	63	4	0	0	
BMR 6 CPVS	66	10	4	8	81	0	2	<0.968
Mob. Nurs.	55	14	35	17	50	1	6	

Despite some differences in magnitude, the data were generally well correlated. The exception was with the identification of BMV 4 virulence, which was considerably higher in both sets of mobile nursery data. One

explanation could lie in cultivar distribution: if BMR 4 cultivars were considerably more frequent in the Cambridge area than nationally, then a higher frequency of the corresponding virulence would be expected. This is not the case however, and it appears that the more likely reason for the discrepancy originates in the difference of technique. It seems that inoculation and incubation of the BMR 4 seedlings in the field rather than in the laboratory leads to higher levels of infection, which fits with other observations of the temperature sensitivity of the BMR 4 resistance: as with a number of other disease resistance genes, BMR 4 is more effective at low than at high temperatures.

If the reaction of the BMR 4 resistance has been correctly interpreted as temperature sensitive, then this characteristic could contribute to the durability of the resistance, since, at high temperatures, a virulent isolate would have little selective advantage.

A more detailed comparison of more comprehensive mobile nursery tests in 1978 with the conventional tests for 1978, also showed a good correlation. It therefore seems that the mobile nursery technique offers a useful potential for quantitative assessment locally of the major selective influence of different host cultivars on the pathogen population.

Pathogen specialisation within BMR groups

From the mobile nursery data obtained in 1978, there was evidence of pathogen specialisation towards individual cultivars within different BMR groups, for example:

a) Within BMR 6

Infection on seedlings of Ark Royal and Wing exposed in fields of six cultivars not possessing the same resistance was similar, with 110 colonies counted on Ark Royal for each 100 on Wing. In three fields of Ark Royal, however, the average infection was different, with 165 colonies on Ark Royal for each 100 on Wing (difference on the original data significant at $P < 0.05$). This suggests that Ark Royal has background resistance different from that in Wing.

b) Within BMR 2+4

When exposed in 12 fields of eight cultivars, none of which possessed the same resistance as Abacus, Georgie and Sundance, seedlings of these three cultivars had infection levels (Table 6) which ranked them in the order shown. When exposed in a field of Sundance the infection levels all increased, due to the occurrence of matching virulence, but the rank order

was reversed (χ^2 test for the changed ratio significant at $P < 0.01$). The data again suggests differences in background resistance, differentially matched by the pathogen.

Table 6. Colony numbers, relative to Golden Promise, on seedlings of Abacus, Georgie and Sundance exposed in fields of cultivars with other resistances, and in a field of Sundance

Test seedlings	Fields of cultivars without BMR 2 and 4	Sundance (BMR 2+4)
Abacus	46	60
Georgie	41	79
Sundance	36	84
χ^2	12.5	
P	<0.01	

c). Within BMR 2+5

Seedlings of five cultivars with BMR 2+5 were exposed in 10 fields of six cultivars which lacked matching resistance, and in one field each of Athos and Porthos (Table 7).

Table 7. Relative infection of five BMR 2+5 cultivars exposed in fields of cultivars lacking BMR 2 or 5, and in a single field of Athos and Porthos

Test seedling	cultivars without BMR 2 and 5	Athos (BMR 2+5)	Porthos (BMR 2+5)
Athos	10	17	13
Printa	17	17	18
Porthos	20	21	25
Uta	25	25	18
Cornel	27	21	26

Because of differences in magnitude between the columns in the original data, the relative colony counts have been converted to percentages of the total for the five cultivars in each column. The ranking of the seedlings when exposed in fields of cultivars without BMR 2 or 5 (non-selective: Col. 1 in Table 7) indicates the background resistance of the cultivars, Athos being the most resistant and Cornel the least. In fields of Athos and Porthos (selective: Cols. 2 and 3 in Table 7) all of the seedlings were more infected because of the presence of pathogen genotypes with virulence for BMR 2 and 5 (original data), but interactions between seedling and field cultivar also occurred as follows:

i) Athos and Porthos seedlings were both relatively more infected in the field of Porthos than in those of non- BMR 2+5 cultivars, suggesting adaptation of the pathogen population to a background factor common to both cultivars.

ii) In the field of Athos, there was a relatively large increase in infection of Athos seedlings compared with those of Porthos ($P < .01$ for the original data) indicating the presence of pathogen genotypes matching a background factor in Athos which is not present in Porthos.

iii) Ranking of infection on seedlings of Cornel and Uta was reversed when they were exposed in fields of Athos or Porthos ($P < .01$ from the original data). The direction of this change suggests that Uta is more similar to Athos, and that Cornel is more similar to Porthos.

The simplest explanation of these interactions is that there are differences in the background resistance of the cultivars within each group but it cannot be excluded that in some pathogen populations there may be selection for a higher degree of matching with major resistance genes. If the differences are entirely due to background factors, then for the BMR 2+5 cultivars there must be at least two such factors, one common to Athos and Porthos, and one in Athos alone.

It is not possible at this stage to indicate whether the background factors within each BMR group are the same or different from those in other groups.

Cultivar diversification

From Table 1 it is clear that there is an increasing number of cultivars with different combinations of BMR genes being produced by plant breeders. From Tables 6 and 7, it is also clear that improved techniques can help to

identify both differences in resistance between cultivars in the same BMR group, and the occurrence of virulence to match those differences. Taken together, these developments raise a number of problems relevant to the classification of cultivars into BMR and DG groups.

For example, Triumph and Dram both possess BMR 6, but each has a second, different factor, so that the two cultivars differ by two factors, just as do the cultivars in, say, BMR 2 and 5. On the other hand, Simon (BMR 8) and Wing (BMR 6) also have one factor in common (Mla4) and differ by two (Mla9 in Simon and Mla7 in Wing), but pathogen populations with matching virulence for Simon and other BMR 8 cultivars are also highly pathogenic on BMR 6 cultivars.

As further information of this kind accumulates it will become necessary to reconsider the classification of the DG groups in order to exploit to the best advantage the difficulties faced by the pathogen.

YELLOW RUST OF BARLEY

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Re-examination of the results of many seedling tests has indicated that Varunda, Mazurka and Bigo all possess a similar specific resistance, R 2. The frequency of V 2 appears to be increasing in the U.K. population of Puccinia striiformis, possibly due to the relatively large acreage of Mazurka. Sultan apparently lacks any specific resistance and has been designated R 0. Adult plant test results have confirmed that Sundance, Abacus, Julia and Zephyr possess the overall resistance R 1. The same tests have shown that R 2 is effective at adult plant growth stages in Bigo and Varunda, but ineffective at these growth stages in Mazurka.

INTRODUCTION

The principal aim of the barley yellow rust survey is the early detection of increased virulence in Puccinia striiformis compatible with specific resistances being exploited in commercial cultivars and breeding lines. In contrast to wheat, only a few barley cultivars possess specific resistances. The detection system used in the UK is very similar to that described for wheat yellow rust by Priestley (1978).

VIRULENCE TEST METHODS

Seedling tests

A total of 80 disease samples were received by post during 1978. These had been collected in a non-ramdom way from Magnum (7 samples), Athene (5), Georgie (4), Goldmarker (4), Jupiter (4), Minak (4) and 34 other cultivars.

Isolates were made from 45 samples; the remainder failed to sporulate after inoculation onto seedlings of the universally susceptible cultivar Berac. Virulence tests were carried out on 45 isolates; one was a mixture and has been excluded from the virulence frequency calculations.

Adult plant tests

Tests to measure the virulence of P. striiformis isolates on adult barley plants were continued in 1978 using the Polythene tunnel technique developed for wheat yellow rust (Priestley & Byford, 1978). Tussocks of 36 barley cultivars were sown on 21 March 1978, inoculated on 5 and 25 May, and assessed for percentage

Table 1. Isolates used in adult plant tests

Code	Cultivar	Region	Site	V factors
74/33	Malta	N	Morpeth	V 1
75/37	Mazurka	E	Cambridge	V 0
75/101	Varunda	YL	Boroughbridge	V 1,2
77/1	Athene	E	Morley	V 1,2
77/22	Firecrest	SE	Sparsholt	V 1

Table 2. Resistance factors to P. striiformis

R factor	Test cultivar	Type*	V detected
R 0	Sultan	-	-
R 1	Astrix	overall	1960
R 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.

Table 3. Virulence factor % frequency

V factor	Common name	1972	1973	1974	1975	1976	1977	1978
V 1	Astrix virulence	93	99	100	97	100	100	98
V 2	Bigo virulence	0	0	0	3	0	18	32
number of isolates tested		55	82	109	69	17	27	44

leaf area infection using the International Scale on 9 June (GS 45-50), 16 June (GS 50-58), 23 June (GS 58-60) and 28 June (GS 68). Details of the isolates used are given in Table 1.

VIRULENCE TEST RESULTS

Increased virulence for seedlings of Varunda, Mazurka and Bigo was first detected in the UK population of P. striiformis in 1972 (Chamberlain & Smith, 1973), 1974 (Priestley, Smith & Byford, 1975) and 1975 (Priestley & Byford, 1976) respectively.

A re-examination of the results of seedling tests on 83 isolates carried out during the last three years suggests that these three cultivars all possess the same resistance (R 2), but the phenotypic expression of the resistance at the seedling stage differs between cultivars. In Varunda and Mazurka it is expressed as a type 2 reaction (reduced sporulation, chlorosis), whereas in Bigo it is a type 0-1 reaction (very little sporulation, chlorosis and necrosis). The results also indicate that Sultan lacks any specific resistance and it has therefore been designated R 0. The list of resistance factors (Table 2) has been amended accordingly.

Sampling was not carried out on a random basis and therefore the virulence frequencies for 1972-8 (Table 3) should be treated with caution. R 1 is virtually ineffective as the frequency of V 1 has remained above 90% since 1972. The frequency of V 2 appears to be increasing possibly due to the relatively large hectarage of Mazurka in those areas from which the samples were obtained.

The results of the adult plant tests (Table 4) confirm the previous observation that R 1 is an overall resistance possessed by Sundance, Abacus, Zephyr and Julia (Priestley & Byford, 1978). However, the results do not confirm the earlier postulation that Hassan and Maris Mink possess a specific resistance.

The results clearly demonstrate that R 2 is effective at adult plant growth stages in Bigo and Varunda, but ineffective at these growth stages in Mazurka. Resistance of the type possessed by Mazurka can be classified as a 'seedling' resistance to comply with the use of the terms 'overall' and 'adult plant' resistance (Zadoks, 1961).

Emir and Goldmarker appear to possess a relatively high level of non-specific resistance.

Table 4. Results of adult plant tests

Values are mean percent leaf area infection.
Boxes are for convenience only and have no statistical significance.
R in body of table denotes resistance at seedling growth stage.

	isolate	75/ 37	77/ 22	74/ 33	75/ 101	77/ 1	
R factor	cultivar						mean
R 1	Sundance	3 R	23	41	26	33	-
	Abacus	12 R	50	52	48	40	-
	Zephyr	4 R	61	66	55	46	-
	Julia	18 R	55	61	62	52	-
R 2	Bigo	5 R	0 R	1 R	16	21	-
	Varunda	16 R	10 R	12 R	34	35	-
	Mazurka	47 R	41 R	46 R	56	47	-
R 0	Emir	11	1	2	6	13	6.7
	Goldmarker	7	13	9	8	24	12.2
	Proctor	21	17	15	18	17	17.6
	Maris Mink	27	15	16	20	26	20.8
	Ark Royal	22	32	20	33	18	25.0
	Midas	31	23	20	21	31	25.2
	Athos	29	21	29	33	31	28.6
	Printa	33	25	32	29	32	30.2
	Aramir	38	26	34	31	26	31.0
	Hassan	44	23	28	31	34	32.0
	Sultan	24	38	40	43	30	35.0
	Mala Abed	28	40	34	44	32	35.6
	Lofa Abed	31	41	34	40	33	35.8
	Porthos	50	33	32	40	35	38.0
	Magnum	45	48	58	49	37	47.4
	Ambre	42	50	48	58	40	47.6
	Jupiter	49	52	52	52	41	49.2
	Firecrest	39	44	61	53	51	49.6
	Minak	48	47	57	49	50	50.2
	Dram	44	48	48	64	48	50.4
	Tyra	45	51	55	59	47	51.4
	Albion	58	55	54	55	44	53.2
	Georgie	47	58	58	58	58	55.8
	Keg	50	62	67	65	39	56.6
	Wing	62	64	66	58	48	59.6
	Simon	67	64	64	52	59	61.2
	Vada	64	58	64	66	62	62.1
	Welam	59	72	67	70	66	66.8

Underlined values have two-factor residuals significantly (P = 0.05) less than zero indicating a large negative interaction between cultivar and isolate.

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BROWN RUST OF BARLEY

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Twenty one isolates of Puccinia hordei Otth. were successfully cultured from 31 samples of brown rust received in 1978. All isolates were identified as race F, which carries virulence for host genes Pa, Pa_2, Pa_4, Pa_5, Pa_6 and Pa_8. In seedling tests with standard isolates of P. hordei, the majority of new spring barley cultivars were susceptible. Mirena carries a previously unidentified resistance and Simon apparently carries gene Pa_3. Trap nurseries sown in commercial barley crops in Devon and Cornwall failed to detect adaptation to partial resistance of the test cultivars as did tests in inoculated nurseries grown in the field and in polythene tunnels.

1978 SEEDLING DIFFERENTIAL TESTS (WPBS)

Thirty two samples of barley brown rust were received of which 21 were successfully cultured. Essentially all isolates came from spring barley varieties grown in Devon and Cornwall, the only exception being one from a spring barley trial at Cambridge. Only one race, the common race F, was recorded and this reflects a similar situation observed in 1977. The results are summarized in Table 1.

In addition to these standard seedling tests, a range of resistant genotypes and cultivars which are being used in WPBS breeding programmes are in the process of being tested against standard isolates of P. hordei. Although the majority of new cultivars are susceptible, some have expressed hypersensitive resistance to certain cultures in the seedling stage and these include the spring cultivars Mirena and Simon.

Mirena was resistant in field tests in 1978 where isolate BRS-76-12, which carries virulence to host genes Pa, Pa_2, Pa_3, Pa_4, Pa_5, Pa_6, Pa_8 and Pa_9, was used. This result was confirmed in the seedling glasshouse tests in which Mirena was resistant to isolates of race A, race F and BRS-76-12. However, a culture of limited virulence obtained from Dr C. Roane, in the

USA was virulent on Mirena in three separate tests, and this suggests that Mirena carries a specific resistance to P. hordei different to previously identified resistances.

Table 1. Classification of isolates of Puccinia hordei and their region of origin, 1978

Isolate BRS-78-	Origin	Cultivar	Race
4	Cambs	S. barley trial	F
6	Devon	Midas	"
7	"	Armelle	"
8	"	Julia	"
9	Cornwall	Lofa Abed	"
10	"	Julia	"
13	"	Aramir	"
14	"	M. Mink	"
18	Devon	Armelle	"
20	"	Aramir	"
21	"	M. Mink	"
22	"	Midas	"
23	"	Vada	"
24	"	Julia	"
25	"	Midas	"
27	"	M. Mink	"
28	"	M. Mink	"
29	"	Julia	"
30	"	Lofa Abed	"
31	"	M. Mink	"
32	"	Midas	"

Simon was susceptible in the field and glasshouse to isolate BRS-76-12 in 1978 but was resistant to race A, race F and the Roane culture (race 4, 57/19) in the greenhouse seedling tests. Its susceptibility to BRS-76-12 in the seedling stage and the characteristic 'Oi' response (definition given in Jones & Clifford, 1978) to other cultures, suggests that Simon carries gene Pa_3. In the standard set of differentials (Clifford, 1977) this gene is carried by Ribari which is a line from Rika x F_1 (Baladi 16 x Rika No. 7), the resistance gene having originated in Baladi 16. Lines carrying gene Pa_3 commonly give low levels of infection with compatible races under field and

glasshouse conditions at WPBS and this is true of Simon also, suggesting that the gene Pa_3 has a pleiotropic effect or is associated with other genetic factors which govern partial resistance to P. hordei. The latter situation has been observed for gene Pa_7 in the cultivar Cebada Capa (Parlevliet and Kuiper, 1977).

1978 TRAP NURSERIES (WPBS/ADAS)

In 1978, a number of trap nurseries was again sown in selected fields of barley in south west England to monitor pathogen variation in relation to partial host resistance. As before, this was a co-operative project between the WPBS and MAFF/ADAS, Starcross, Devon. The nurseries, consisting of eight replicates each of the cultivars Lofa Abed, Armelle, Hassan, Aramir, Maris Mink, Midas, Vada and Julia, were sown at ten different locations where percentage levels of brown rust infection were measured. No evidence of higher than expected levels of infection was obtained but the procedure continues to offer the best possibility of early detection of pathogen variants and will be continued in 1979.

1978 ISOLATION NURSERIES (WPBS)

Twenty spring cultivars which differ in their degree of partial resistance and including those grown in the trap nurseries described above (except Julia) together with Jupiter, Goldmarker, Magnum, Athos, Porthos, Mala Abed, Mazurka, Proctor, Georgie, Sundance, Tyra, Tintern and Coracle, were grown as replicated clumps, in isolated field nurseries as described previously (Clifford, Jones and Priestley, 1978). Four nurseries were sown and inoculated separately with individual cultures of P. hordei. The cultures were:

1. Standard race F. Pa, Pa_2, Pa_4, Pa_5, Pa_6, Pa_8 virulent
2. BRS-76-12 (as race F + Pa_3, Pa_9 virulent)
3. BRS-76-6 race F, ex Armelle
4. C/479 (as race F + Vada virulence)

No significant race x cultivar interactions were detected and this confirms the results of the 1977 nursery tests where the same isolates were included.

1978 POLYTHENE TUNNEL TESTS (NIAB)

The spring cultivars tested in the isolation nurseries described above, together with Bigo, Abacus, Ambre, Julia, Emir, Ark Royal, Printa, Dram, Keg, Varunda, Firecrest, Welam, Wing and Zephyr, were tested in polythene tunnel nurseries to the following isolates:

Table 1. Results of adult plant Polythene tunnel (NIAB) tests

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

Sowing date: 21 March 1978
Inoculation dates: 5 May and 25 May 1978
Assessment dates: 9 June, 16 June, 23 June and 28 June 1978
R = resistant reaction at seedling stage.

Isolate:	BR/EST	race F	BR/CTI243	BR/C479/C	mean
Cultivar:					
Simon	42	1R	OR	1R	-
Magnum	4	16	8	7	8.8
Bigo	6	23	8	9	11.5
Mala Abed	6	21	17	5	12.3
Vada	6	19	12	19	14.0
Lofa Abed	5	31	9	12	14.3
Sundance	19	20	14	10	15.8
Abacus	7	32	15	17	17.8
Ambre	14	35	14	8	17.8
Julia	13	32	23	7	18.8
Maris Mink	14	30	18	15	19.3
Porthos	20	37	18	14	22.3
Emir	16	21	26	16	23.3
Ark Royal	17	35	30	17	24.8
Athos	27	32	21	22	25.5
Georgie	19	32	21	34	26.5
Printa	30	34	29	19	28.0
Proctor	16	45	31	23	28.8
Dram	24	43	21R?	29	29.3
Aramir	26	40	23	30	29.8
Jupiter	22	45	32	22	32.0
Keg	29	41	35	24	32.3
Varunda	24	39	34	33	32.5
Firecrest	34	44	31	34	35.8
Hassan	40	42	30	31	35.8
Mazurka	34	47	32	32	36.3
Goldmarker	23	50	34	39	36.5
Midas	30	52	37	29	37.0
Albion	36	46	39	35	39.0
Minak	28	48	46	42	41.0
Tyra	36	44	45	41	41.5
Welam	36	55	46	37	43.5
Sultan	37	56	48	37	44.5
Wing	40	53	45	40	44.5
Zephyr	40	59	47	45	47.8
LSD (P = 0.05)	14	13	11	15	

1.	BR/CI 1243	CI 1243 (Pa_9) virulent
2.	BR/C 479/C	Vada virulent
3.	BR/EST	Pa_3 virulent
4.	Race F	Pa, Pa_2, Pa_4, Pa_5, Pa_6, Pa_8 virulent

The results are given in Table 1. Differences in levels of infection between cultivars were observed, confirming the known range of partial resistance in spring barley cultivars. In general, the ranking order of cultivar susceptibility confirmed that reported here for isolation nurseries in 1978 and in polythene tunnels and isolation nurseries in 1977 (Clifford, Jones & Priestley, 1978). However, Hassan and Tyra appeared more susceptible under polythene tunnel conditions than in isolation nurseries in 1978. Furthermore, the results shown in Table 1 failed to confirm the significant interactions between Sultan, Albion, Goldmarker, Minak and specific isolates of P. hordei as reported previously (Clifford et al, 1978). These anamolous results are probably the result of cultivar x isolate x environment interactions. Simon was resistant to three isolates but susceptible to isolate BR/EST confirming the seedling tests reported here which indicate that this cultivar possesses resistance factor Pa_3.

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RHYNCHOSPORIUM OF BARLEY

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Of the 66 samples received in the 1978 survey, 54 were from winter varieties, mainly from Wales and south west England. Thirty seven were successfully cultured and of these,11 were classified as race UK1 and 26 as race UK2. Hitherto undetected variation in virulence was observed in some isolates when tested on a set of winter cultivars. Some variants of race UK1 were avirulent on Astrix, Katy and Mirra. One of these (Rs-78-63) gave higher than expected levels of infection on Athene and Hoppel and another (Rs-78-50) on Athene and Igri. Variants of UK2 gave high levels of infection on specific winter cultivars including Athene, Hoppel and Igri. These results require confirmation under field conditions.

MATERIALS AND METHODS

Sixty six samples were recieved from the 1978 Survey of which 54 were from winter varieties, 11 from spring varieties and one from a volunteer plant. The majority of samples were from Wales and south-west England as can be seen from the summary of cultivars and regional origins given in Table 1. Of the 66 samples, 37 were successfully cultured and tested on the standard set of differentials which includes Maris Mink and Truimph (susceptible check varieties), Armelle (factor Rh) and La Mesita and Magnum (factor Rh_4). In addition, all viable isolates were tested on a set of winter cultivars using the procedures described previously (Clifford and Jones, 1978). The winter cultivars included Maris Otter, Sonja, Astrix, Hoppel, Athene, Igri, Mirra, Maris Trojan and Katy. The plant responses to infection were assessed on a percentage basis and also as reaction types according to the following conventions which are based on those of Ali and Boyd (1974) : 0 = no visible lesion or symptom; 1 = small lesion(s) on margin of leaf blade; 2 = narrow band(s) of lesion(s) extending the length of leaf blade; 3 = well developed lesion(s) on leaf blade; 4 = large area(s) of infection. No evidence of discrete lesions.

Table 1. Origin of samples of Rhynchosporiu

	Wales	South-west	N Wes
Winter variety			
Sonja	6	2	1
Igri	3	2	1
Athene	3	2	1
Otter	2	1	1
Hoppel	1	1	1
Katy	1	1	
Astrix	2		
Gerbel	1		1
Trojan	1		
Spring variety			
Armelle		3	
Minak	1		1
Tyra	1		
Magnum	1		
Georgie			1
Athos	1		
Rye	1		
Volunteer	1		
Sp. Barley Trial			
W. " "			
Total	26	12	8

RESULTS

Based on the set of standard differentials races UK1 and UK2 were identified, there be of the latter. This confirms the widespread ries virulence for the host resistance factor ieties. No virulence for resistance Rh_4, whic

Table 2. Response of spring and winter differential v

Isolate Rs-78- / Differential	M. Mink		La Mesita		Triumph	
	%	RT	%	RT	%	RT
2. Sonja	50	4-2	0	-	70	4-2
3. Sonja	70	4-2	0	-	80	4-2
5. Athene	50	4	0	-	60	4,3
6. Igri	60	4-2	0	-	70	4-2
7. Sonja	70	4-2	0	-	70	4-2
12. Sonja	90	4	0	-	90	4
13. Sonja	70	4-2	0	-	90	4-2
14. Katy	70	4,3	0	-	80	4
15. Igri	80	4	0	-	90	4
16. Athene	80	4	0	-	80	4
17. M. Otter	90	4	0	-	90	4
19. Katy	60	4,3	0	-	80	4
22. Athene	70	4-2	0	-	80	4,3
23. Igri	80	4	0	-	90	4
28. Athene	60	4-2	0	-	70	4,2
29. Athene	90	4	0	-	90	4
32. M. Otter	80	4	0	-	90	4
39. Volunteer	90	4	0	-	80	4
42. M. Otter	60	4-2	0	-	80	4
43. Katy	80	4,2	0	-	70	4,2
45. Hoppel	60	4-2	0	-	70	4
46. Gerbel	50	4-1	0	-	80	4
47. Sonja	60	4-2	0	-	60	4,3
49. M. Otter	60	4-1	0	-	40	4-2
50. Minak	60	4	0	-	70	4,2
51. Igri	50	4,3	0	-	80	4,3
52. Igri	50	4-2	0	-	80	4,2
53. Hoppel	60	4-2	0	-	70	4
54. Gerbel	60	4,2,1	0	-	80	4
55. Athene	40	4,2,1	0	-	90	4
56. M. Otter	80	4	0	-	80	4
57. Sonja	60	4-2	0	-	60	4-2
58. Sp. Barley Trial	90	4	0	-	80	4
60. Igri	70	4	0	-	90	4
62. Tyra	50	4-1	0	-	60	4-2
63. Minak	50	4,2	0	-	60	4-2
64. Magnum	80	4	0	-	80	4

arieties to isolates of Rhynchosporium secalis, 1978

Magnum		Armelle		M. Otter		Sonja		Astrix		Hoppel		Athene		Igri		Mirra		M. Trojan		Katy		Race
%	RT	%	RT	%	RT	%	RT	%	RT	%	RT	%	RT	%	RT	%	RT	%	RT	%	RT	
0	-	3	1,3																			1
0	-	50	4-2	8	2-4	0	-	3	3,2	0	-	2	2,1	0	-	5	3-1	2	3,1	0	-	2
0	-	40	4-2	50	4	5	3,2	5	4,2	20	4-2	15	4-2	25	4-2	0	-	15	3-1	0	-	2
0	-	50	4-2	10	4,3,1	0	-	10	4-1	0	-	8	4-1	10	4-2	10	4-2	5	3-1	2	2	2
0	-	5	1,3	15	4-2	0	-	0	-	0	-	2	2,1	1	1	0	-	3	3,1	0	-	1
0	-	40	4,3	15	4-2	3	1-3	3	2,3	0	-	5	1-3	5	1-3	2	3,1	10	1-3	0	-	2
0	-	0	-	15	4-2	0	-	0	-	0	-	3	2,1	1	1	0	-	2	2,1	0	-	1
0	-	50	4,3	15	4-2	5	4	15	4-2	8	4,3	5	2-4	5	4,2	15	4-2	3	3,1	5	4	2
0	-	70	4,3	15	4-2	10	4-1	5	4	0	-	5	4,2,1	15	4	20	4,1	3	2	2	2,1	2
0	-	70	4,3	30	4,3	5	3,2	5	4-1	8	4,3	3	2,1	5	4,2,1	5	4-2	5	3-1	5	3-1	2
0	-	0	-	15	4-2	5	4,2	15	4,2,1	8	4,2	8	4,2,1	10	4,3,1	10	4	15	4-2	5	3,2	V
0	-	50	4,3	30	4,2	3	3,1	5	3-1	5	3-1	5	3-1	10	4,3,1	5	3-1	8	3-1	0	-	2
2	1*	80	4,3	8	4-2	3	1,3	5	3-1	3	3,1	5	4,3,1	5	4,3	5	4,3	5	1-3	0	-	2
0	-	40	3-1	15	4	3	3,2	2	2,1	5	4	5	4,2	5	4	0	-	15	4-2	1	1	2
0	-	70	4	25	4,3	10	4,3	30	4,3	15	4,3	40	4-2	40	4-2	15	4,3	10	3,2	25	4-2	2
2	2*	90	4	50	4,3	25	4-2	30	4-2	30	4,2	50	4	15	4	25	4	15	4,3	10	4,3	2
0	-	70	4-2	5	4-1	3	3,1	5	1-3	0		3	1,3	5	4	0	-	2	2	0	-	2
0	-	0	-	40	4	5	4	0	-	5	4	15	2-4	5	4	0	-	8	4	0	-	V
0	-	0	-	20	4,3,1	0	-	0	-	3	3,1	5	3,1	1	1	3	3,2	5	3-1	0	-	1
0	-	50	4-2	40	4-1	10	3-1	5	3-1	15	4-2	15	3-1	20	4,3,1	30	4,2,1	15	4-1	5	3-1	2
2	2*	60	4	20	4,2	15	4	15	4,2	20	4,3	30	4	15	4-2	20	4-2	5	4,2,1	10	4,2	2
0	-	50	4,2	15	4-2	10	4-2	8	4-2	5	3-1	10	3-1	10	4,3	15	4-2	15	4-1	10	2-4	2
0	-	60	4	20	4-2	10	1-3	15	4,3	15	4-2	15	4-2	8	4,1	15	1-3	10	4-1	8	2-4	2
0	-	0	-	5	4,2,1	0	-	0	-	3	2,3	0	-	0	-	0	-	0	-	0	-	1
0	-	0	-	60	4	20	4,3	0	-	20	4-2	30	4-2	30	4-2	0	-	20	4-1	0	-	V
2	2*	70	4	30	4,3	20	4-2	15	4,2	25	4	30	4,2,1	20	4	20	4	10	4,3	20	4,3	2
0	-	60	4	40	4-2	20	4-2	25	4,2	15	4	8	4,1	20	4,2	40	4-2	25	4,3	10	4,2	2
0	-	60	4,3																			2
0	-	80	4																			2
0	-	70	4-1	5	4-2	2	3,1	1	1,3	3	2-4	3	1-3	2	1,3	1	1	5	1,3	3	1,3	2
0	-	1	1	5	1-4	0	-	0	-	0	-	0	-	3	1,3	0	-	1	-	0	-	1
0	-	70	4,2	15	4-2	8	4-2	5	4-2	15	4,3,1	25	4-2	15	4-2	15	4-2	10	3-1	5	3-1	2
2	2*	0	-	70	4,3	5	4	0	-	20	4,2	15	4,2	15	4,3,1	0	-	5	2,4,1	0	-	V
0	-	40	4-2	5	3-1	5	3-1	5	3-1	5	3-1	5	3-1	0	-	10	4,3,1	3	3-1	0	-	2
0	-	50	4-2	30	4-2	5	3-1	0	-	15	4-2	10	4,2,1	5	4,3,1	0	-	15	4-1	0	-	2
0	-	0	-	50	4,2	20	4-2	0	-	30	4,2	40	4-2	10	4,2,1	0	-	20	4-2	0	-	V
0	-	20	1-3	20	4,3	5	3-1	1	1,3	10	4,2	8	4,1	10	4,2	0	-	10	4,3	0	-	2

= Mixed

V = Variant (Unclassified), 1 = Race UK1, 2 = Race UK2

Magnum and the differential variety La Mesita, was detected; the one sample that was received from a presumptive Magnum was classified as race UK2.

The tests on the set of winter cultivars allowed further classification of the isolates to be made and indicate that hitherto undetected variation for virulence exists in the pathogen population. Specifically, a number of isolates which were classified as race UK1 by their incompatible interaction with Armelle, gave unusual responses on the winter cultivars. These have been classified as variants (V) in Table 2. Each of these isolates, namely Rs-78-39, -50, -58 and 63 was avirulent on Astrix, Mirra and Katy but virulent on Sonja, Hoppel, Athene, Igri and Maris Trojan. This suggests that Astrix, Mirra and Katy have a resistance factor in common. In addition, within this group, quantitative differences in infection were observed on the susceptible cultivars and these responses are summarized in Table 3.

Table 3. Quantitative responses of the winter differential cultivars to specific isolates of Rhynchosporium secalis

	Differential							
	Sonja	Astrix	Hoppel	Athene	Igri	Mirra	Trojan	Katy
Isolate								
Rs-78-17	+	++	+	+	+	+	++	+
28	+	+++	++	+++	+++	++	+	+++
29	+++	+++	+++	+++	++	+++	++	+
39	+	-	+	++	+	-	+	-
50	++	-	++	+++	+++	-	++	-
51	++	++	+++	+++	++	++	+	++
58	+	-	++	++	++	-	+	-
63	++	-	+++	+++	+	-	++	-

- No infection ++ 15-20% infection
+ 5-10% infection +++ 25-40% infection

Specifically, isolate Rs-78-63 gave high levels of infection on Athene and Hoppel and isolate Rs-78-50 gave high levels on Athene and Igri. A further group of isolates, classified as Race UK2, gave higher than expected levels of infection on particular varieties. Isolate Rs-78-29 was highly infective on Athene,

Astrix, Sonja, Hoppel and Mirra, and isolate Rs-78-51 showed high levels on Athene and Hoppel and was therefore similar to isolate Rs-78-63. Isolate Rs-78-28 was specifically adapted to Athene, Igri, Astrix and Katy.

It must be emphasized that such quantitative tests are subject to error and results will need to be confirmed by further laboratory tests and by field tests in isolation nurseries in 1979. The results do however, confirm the 1978 field observations of high levels of infection on the previously resistant Igri. Also, the variation detected in relation to Athene may explain the discrepancy between its high NIAB rating (8) and some laboratory test results.

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MILDEW OF OATS

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As in previous years, virulence to all seedling resistance factors incorporated in commercial cultivars was detected in 1978, the combined virulence OMV 1 + 2 + 3 (Race 5) being again the most common.

The next most frequent virulence combination was OMV 1 + 2 (Race 3) which is able to attack all varieties with Cc 4146 resistance but not the Mostyn (OMR 3) group. In Scotland and Eire this was the most common virulence.

The virulence OMV 1 + 3 (Race 4) attacking Mostyn but not Cc 4146, showed a drastic decline, probably reflecting the reduced area sown to Mostyn. The OMV 1 virulence (Race 2) remained at very low frequency.

Virulence to the new source of resistance now being introduced from A. barbata into various breeding programmes was not detected in the 1978 survey samples. However, virulence has been detected and confirmed under glasshouse conditions, and 1979 field samples will be closely monitored for its presence.

NOMENCLATURE

In order to standardize the nomenclature used in this survey, the Oat Mildew Resistance (OMR) symbols in the host and the corresponding Oat Mildew Virulence Groups (OMV) in the pathogen are given in Table 1. This table also gives the physiologic race number (1 - 5) by which the different virulence groups have been previously designated, together with the standard differential cultivars, and examples of cultivars which belong to the various resistance groups.

Table 1. Oat Mildew Host Resistance Groups (OMR) and corresponding Pathogen Virulence Groups (OMV)

OMR group	Differential cultivar	Other cultivars	Oat Mildew Virulence Group (OMV)				
			0 (1)*	1 (2)	1 + 2 (3)	1 + 3 (4)	1 + 2 + 3 (5)
0	Milford	Selma, Astor Condor, Leanda Saladin Maris Quest	+	+	+	+	+
1	Manod (01747/10/7)‡	Peniarth Maris Osprey	-	+	+	+	+
2	Cc 4146	Maris Tabard Maris Oberon Nelson, Margam Trafalgar	-	-	+	-	+
3	9065 Cn 6/3/74 (Cc 4346)	Mostyn, Panema	-	-	-	+	+

\+ = Compatible reaction; - = Incompatible reaction
* = Physiologic race designation having the particular virulence is given in parenthesis
‡ = Original source of resistance in parenthesis

GENERAL OBSERVATIONS

A total of forty six samples were received, thirteen of which failed to culture. Location and host cultivar details of the thirty three samples which were cultured are given in Table 2. The samples were obtained from a wider geographical distribution than in the previous year.

The frequency of occurrence of the various virulences in 1978, compared with those of the two previous years, is given in Table 3.

Table 2. Race identification giving location and cultivars from which mildew samples received

Location		Cultivars (with race identified in parenthesis)
WALES	Bangor, Gwynedd	Maris Oberon (3), Leanda (5), Maris Tabard (5), Trafalgar (5), Margam (5), Siluria (5)
	Trawscoed, Dyfed	Orlando (2), Margam (3), Leanda (3), Maris Oberon (5), Siluria (5)
	Llanilar, Dyfed	Volunteer ? seedlings (5)
	WPBS, Aberystwyth, Dyfed	Nelson (3), 9065 Cn (4), Maris Tabard (5), Mostyn (5), Milford (5), Saladin (5), Trafalgar (5)
ENGLAND	Wye, Kent	Maris Quest (3), Maris Oberon (3), Margam (5)
	Slate Hall, Cambridge	Trafalgar (5), Maris Tabard (5)
SCOTLAND	Dumfries	Saladin (3), Leanda (3), Maris Oberon (3), Trafalgar (3), Maris Tabard (3)
EIRE	Co. Kildare	Astor (3), Nelson (3), Maris Oberon (3), Mostyn (5)

Table 3. Race and virulence group frequencies identified from samples received in 1978 compared with the results of the previous two years

Race (virulence group)	No. of isolates in 1978	Frequency (% of total) 1978	1977	1976
2 (OMV 1)	1	3	5	19
3 (OMV 1 + 2)	14	42	25	26
4 (OMV 1 + 3)	1	3	35	26
5 (OMV 1 + 2 + 3)	17	52	35	29

As in the previous three seasons, four mildew races were detected, namely races 2, 3, 4 and 5, which, collectively, carry virulence to all known seedling resistance factors already incorporated in commercial varieties.

VIRULENCE FREQUENCY

As in 1976 and 1977, Race 5 (OMV 1 + 2 + 3), which has combined virulence to all commercially used seedling resistance factors, was again the most frequently identified race; it was isolated in 52% of the samples which is a higher proportion than in any other year. As in previous years it was found occasionally on cultivars of the OMR O group e.g. Leanda, Saladin and Milford with no known seedling resistance genes, indicating that it is able to compete satisfactorily with other less complex races. This virulence combination was detected in most of the samples from England and Wales, and on one sample of Mostyn from Eire, but not from Scotland in this season. It was first detected in Scotland and Eire during 1976.

The next most common virulence was OMV 1 + 2 (Race 3) observed in 42% of the samples, thus showing a considerable increase over its frequency in 1976 and 1977 (Table 3). It is virulent to OMR group 1 (Manod) and OMR 2 (Cc 4146) but not to OMR 3 (9065 Cn 6/3/74 and Mostyn), and was the most frequent virulence in samples from Scotland and Eire. This may be due to the fact that a smaller area has been sown to Mostyn in Scotland and Eire than in England and Wales in past years and so the pathogen did not have to accumulate virulence to OMR groups 1, 2 and 3 in order to survive.

Race 4 (OMV 1 + 3), virulent on Manod and 9065 Cn and Mostyn but avirulent on Cc 4146 and cultivars such as Maris Tabard and Trafalgar, showed a very marked decrease in 1978, being detected only on the differential cultivar in the WPBS breeding nursery. Undoubtedly, this reflects the reduced area being sown to Mostyn in 1978 and also indicates that the most common race, Race 5 (OMV 1 + 2 + 3), with the added factor for virulence to Cc 4146, is well able to colonize and multiply on Mostyn.

As in 1977, Race 2 (OMV 1) the simplest race was again identified only in one sample from the cultivar Orlando.

The general trend observed in previous years has continued in 1978 with Races 5 and 3 showing a combined frequency of 94% of the total samples. This ensures virulence to all cultivars with Cc 4146 resistance, which now constitute most of the area sown with spring oats.

A new source of seedling resistance, effective against all the known oat mildew virulences, has been incorporated into a hexaploid genotype by translocation into the variety Manod from the tetraploid Avena barbata (Aung, Thomas and Jones, 1977). Because this translocation line, known as Cc 6490, is now being incorporated into the breeding programmes of various organizations, the genotype was added to the tester cultivars in all tests carried out in the 1978 survey, in order to detect whether any virulences to it already exist in the oat mildew population. The results showed that this resistance is very effective since most of the mildew samples produce an immune or highly resistant reaction. In one test, Cc 6490 gave slight sporulation but there was no evidence of a 'breakdown' of the resistance. However, in the field at WPBS, a few pustules were isolated on this material. Under glasshouse conditions they have been found to produce a completely compatible reaction on the translocation Cc 6490 and the original A. barbata source of resistance. Any build-up of this virulence under field conditions will be closely monitored and reported.

REFERENCE

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CROWN RUST OF OATS

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Seven samples, all from Wales, were received, three of which failed to culture. Race 251, which is virulent on Appler, Bond and Saia, was identified on samples from Mostyn, 06616Cn and *Avena hirtula*. A mixture of races 251 and 265 was identified on a sample from a Maris Oberon backcross translocation line.

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 1977 Annual Report.

VARIETAL DIVERSIFICATION SCHEME TO REDUCE RISK OF YELLOW RUST IN WINTER WHEAT 1979

Where winter wheat crops are grown adjacent to each other, or in the same field in successive years, the risk of severe yellow rust infections can be reduced by using varieties that possess different resistance factors. Each diversification group (DG) below consists of varieties possessing similar resistance factors. Thus the risk of disease in an area can be reduced by growing only one variety from within each diversification group. The only exception to this is that varieties in DG 1 may be sown adjacent to one another because they are resistant to yellow rust spreading from all other varieties.

DG 1
Anvil
Aquila
Armada
Atou
Bouquet
Bounty
Brigand
Flanders
Fleurus
Flinor
Iona
Kador
Mardler
Maris Widgeon
Sentry
Valmy
Wizard

DG 2
Copain
Hustler
Maris Huntsman
Maris Nimrod
Maris Templar
Sportsman
Virtue

DG 3
Kinsman
Maris Freeman
Maris Ranger

DG 4
Mega

DG 5
Cappelle-Desprez
Champlein
Waggoner

DG 6
Hobbit
Score

DG 7
Clement

Choosing varieties to grow adjacent to one another

In the table below, + signs indicate those combinations of DGs that can reduce the risk of yellow rust when single varieties from different groups are grown adjacent to one another. It should be noted that DG 1 is exceptional in that individual varieties from this group may be grown adjacent to each other.

Chosen DG	DGs that can reduce risk of yellow rust when grown with chosen DG						
	DG 1	DG 2	DG 3	DG 4	DG 5	DG 6	DG 7
DG 1	+	+	+	+	+	+	+
DG 2	+	.	+	+	.	+	+
DG 3	+	+	.	+	.	+	+
DG 4	+	+	+	.	+	+	+
DG 5	+	.	.	+	.	+	+
DG 6	+	+	+	+	+	.	+
DG 7	+	+	+	+	+	+	.

Spring wheat varieties

Spring wheat crops should not be grown adjacent to susceptible winter wheat varieties as these may act as a source of infection for the spring crop. If this is unavoidable, choose spring varieties with a high level of resistance.

VARIETAL DIVERSIFICATION SCHEME TO REDUCE SPREAD OF MILDEW IN SPRING BARLEY 1979

Where spring barley crops are grown adjacent to each other, or in the same field in successive years, the spread of mildew between crops can be reduced by using varieties that possess different resistance factors. Each diversification group (DG) below consists of varieties possessing similar resistance factors. Thus, disease levels in an area can be reduced by growing only one variety from within each diversification group. The only exceptions to this are a) varieties in DG 0 which do not contribute because they are susceptible to mildew spreading from all other varieties, and b) varieties in DG 1 which may be sown adjacent to one another because they are resistant to mildew spreading from all other varieties.

DG 0
Armelle
Clermont
Freegold
Golden Promise
Imber
Julia
Proctor
Zephyr

DG 1
Magnum
Simon
Welam

DG 2
Midas

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

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
Tyra

Choosing varieties to grow adjacent to one another

In the table below, + signs indicate those combinations of DGs that can reduce mildew spread when single varieties from different groups are grown adjacent to one another. It should be noted that DG 1 is exceptional in that individual varieties from this group may be grown adjacent to each other.

Chosen DG	DGs that can reduce mildew spread when grown with chosen DG						
	DG 1	DG 2	DG 3	DG 4	DG 5	DG 6	DG 7
DG 1	+	+	+	+	+	+	+
DG 2	+	•	+	•	+	+	+
DG 3	+	+	•	•	+	+	+
DG 4	+	•	•	•	+	+	+
DG 5	+	+	+	+	•	+	+
DG 6	+	+	+	+	+	•	+
DG 7	+	+	+	+	+	+	•

Winter barley varieties

Susceptible winter barley varieties may act as a source of infection for local spring barley crops. Thus, susceptible spring barley varieties should not be grown close to these crops.