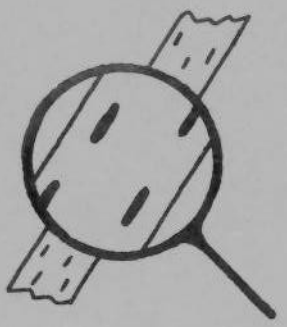
PHYSIOLOGIC RACE SURVEY

(CEREAL PATHOGENS)



1975 Annual Report

PHYSIOLOGIC RACE SURVEY (CEREAL PATHOGENS)

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The paper on yellow rust of wheat includes an appendix with the results of the UK and Eire section of the International Survey of Factors of Virulence of Puccinia striiformis.

THE PHYSIOLOGIC RACE SURVEY OF CEREAL PATHOGENS

The Survey was commenced in 1967 following an unexpected epidemic of wheat yellow rust (Puccinia striiformis) that caused severe losses in the recently introduced but widely grown winter wheat cultivar Rothwell Perdix. This cultivar had previously been resistant to yellow rust and the epidemic was caused by a new physiologic race carrying previously unknown virulence genes.

The Survey is supported by the MAFF and ARC.

OBJECTIVES

The principal objective is the detection of new virulence genes and gene combinations in the UK population of cereal pathogens.
Secondary objectives include the monitoring of virulence gene and gene combination frequencies, evaluating the compatibility of virulence genes with one another and measuring the effect of varietal changes on the pathogen population.

OPERATION

Each spring a list of cereal varieties from which disease samples are required is circulated to about 100 pathologists and agronomists in the UK. Samples are collected from field crops and cultivar trials (not at random) and sent by post to the three testing centres:

NIAB for yellow rust of wheat and barley
PBI for mildew of wheat and barley
WPBS for brown rust of wheat and barley, mildew and crown rust of oats and Rhynchosporium of barley.

About 1000 samples are received each year from which isolates are made for inoculation onto seedlings or leaf segments of standard differential cultivars undercontrolled environment conditions. At a later date these are assessed for resistance or susceptibility and the virulence factors in each isolate are determined.
Recently, tests involving adult plants grown in polythene tunnels have been introduced for yellow rust of wheat. The information from these tests is used to supplement data from seedling tests.

RESULTS

An Annual Report (such as this) is prepared each May and about 150 copies are sent to NIAB personnel, MAFF advisors, BAPB members, ARC breeding Institutes, Universities and Colleges, and overseas Institutes. The Annual Report contains papers from the three testing centres about the nine diseases surveyed giving details of the isolates identified. In the case of some diseases, physiologic race and virulence gene frequencies in the pathogen population are also given.

UTILIZATION OF RESULTS

The information provided by the Survey is utilized in four ways:

(a) Isolates containing new virulence genes are used by the NIAB to evaluate the resistance of cereal cultivars under trial. There are many cases of cultivars not being recommended by the NIAB owing to their susceptibility to new isolates of cereal pathogens found by the Survey.

(b) These isolates are also distributed to plant breeders who use them to select new lines with adequate forms of resistance. Many breeding programmes have been terminated because of the presence in the pathogen population of isolates found by the Survey to contain previously unknown virulence genes.

(c) Advisory pathologists use the results of the Survey to supplement NIAB advice in recommending to farmers those cultivar combinations that minimise the risk of widespread heavy infections.

(d) Isolates are regularly supplied to universities and colleges to illustrate to students the principles of resistance in host-pathogen systems and for use in research projects in areas relating to the techniques of the Survey.

Much of the benefit resulting from (a) and (b) is not realised by farmers and consumers as these people never see the extremely susceptible lines and cultivars that are rejected by breeders or not recommended by the NIAB.

FUTURE DEVELOPMENTS

In order to realise its objectives the Survey actively supports research projects at the three testing centres. All the projects are aimed at improving our knowledge of the pathogen population and at present include the use of mobile nurseries, quantitative seedling infection measurements, detection of adult plant resistance genes, fungicide insensitivity and new analytical techniques.

SUMMARIES

A short summary of each paper is given.

Yellow rust of wheat

An isolate from a severely infected field of M Huntsman in N England in 1974 has shown increased specific virulence on adult plants of M Huntsman in a Polythene tunnel test in 1975. The level of specific adult plant virulence on M Huntsman was less than on M Nimrod with all virulent isolates.

A total of seven specific adult plant virulences were detected; that for Clement was identified for the first time and that for Mega confirmed the identification of this virulence in 1974.

Virulence for Riebesel 47/51 at the seedling stage (factor 10) was identified for the first time.

Race 1,2,3 (formerly 41 E 136) was again the most frequently identified race. It has seedling virulence for M Templar, M Huntsman and many other varieties but is avirulent on M Ranger, M Freeman, Kinsman and M Dove.

Race 2,3,4,6 (formerly 108 E 173) was again identified frequently. This race is seedling virulent on M Ranger, M Freeman, Kinsman, M Dove and many other varieties but avirulent on M Templar.

Race 1,2,3,6 (formerly 45 E 140) has increased its frequency since 1974. This race is seedling virulent on many varieties including M Templar, M Huntsman, M Ranger, M Freeman, Kinsman and M Dove.

Four new seedling races were identified: 2,3,6; 1,2,3,4,6; 1,2,3,6,7 and 1,2,3,4,6,10, all at a low frequency. Race 1,2,3,4,6,10 is the first race identified with virulence on Riebesel 47/51 and has shown some virulence on seedlings of the variety Clement. The other races are new combinations of previously identified virulences.

Yellow rust of barley

Race 1,5 (formerly race 24) was the most frequently identified in 1975 and has been so since 1972. It is virulent on most spring and winter varieties with the exception of Mazurka and Varunda. Virulence for Mazurka and Varunda has again been identified but is still at a low frequency.

Virulence for Bigo (Factor 2) was identified for the first time.

Races 3,5 and 1,2,3,4,5 were identified for the first time. Race 1,2,3,4,5 is virulent on all the differential varieties used in the test and therefore on most, if not all, commercial barley varieties. Race 3,5 is a new combination of previously identified virulences.

Brown rust of barley

Two new races (BRMN-75-16 and BRMN-75-7) were identified from samples collected in Norfolk, Oxfordshire, Devon and Dyfed.

Brown rust of wheat

Most of the samples tested appear to be mixtures and so the race picture is not clear. Further tests are being carried out.

Crown rust of oats

Only two samples were received and both were found to be previously identified races.

Mildew of barley

All isolates were tested as bulk samples. They were inoculated in a settling tower and the number of established colonies on the test varieties were expressed as a percentage of those on the control variety Golden Promise. The broad pattern of relationships of the pathogen populations selected by different resistant hosts was confirmed, but it was also revealed that there was considerable interference between plots which were sampled. The majority of the newer varieties which have R2 combined with some other resistance possess Mlg but not the linked factor 'x'. It appears that R2 + 5 varieties Aramir and Maris Mink select pathogen populations with different characteristics. No virulence was detected for MC20 which carries the Mlo resistance.

Mildew of wheat

All isolates were tested as bulk samples. They were inoculated in a settling tower and the number of established colonies on the test varieties were expressed as a percentage of those on the control variety Minister. Virulence for Ulka, which possesses the Pm_2 resistance was more common on non-Pm_2 varieties than in previous years. Two populations showed a similar development of numerous colonies on Maris Fundin, Maris Huntsman and CI 12633, and two other populations showed a high frequency of virulence for Maris Huntsman. An isolate from Sappo had virulence for Ulka and Weih M1 (which has the T. carthlicum resistance). An isolate from Clement was virulent on St 14/44 confirming that this variety possesses therye mildew resistance gene. Mobile nursery data showed that Maris Huntsman performs better than related varieties even in areas with a high frequency of R2 + 6 virulence.

Mildew of oats

Race 4, virulent on Mostyn, was the most frequently identified race. Races 2, 3 and 5 were also identified.

Rhynchosporium of barley

Approximately half of the samples received were identified as race UK 1 and half as UK 2. An isolate has been identified with specific adaptation to the susceptible cultivar Maris Otter.

YELLOW RUST OF WHEAT

BY R H PRIESTLEY & P BYFORD

National Institute of Agricultural Botany, Cambridge

1. ADULT PLANT TESTS WITH 1974 POTENTIAL FIELD VARIANTS

1.1 Isolates used in tests

Twelve potential field variants which were collected in 1974, 6 control isolates from previous years, an isolate from the NIAB trial ground and a mixture of all the isolates were used (Table 1).

1.2 Materials and methods

Three replicate tussocks of each of 24 wheat varieties were sown in 20 Polythene tunnels in the autumn of 1974. The tussocks were inoculated (1 isolate per tunnel) on 8 - 11 April 1975 (GS 20 - 30) and assessed using a modified version of the International Scale on 22 May (GS 37), 3 June (GS 45) 17 June (GS 58) and 2 July (GS 70).

1.3 Results

Mean Percent Attack (PA) values calculated from all replicate tussocks and assessment dates are shown for each variety-isolate combination (Table 2). Specific virulences at the adult plant stage (relatively high mean PA values) are shown in boxes and the varieties are grouped according to their specific adult plant resistances.

Six of the isolates (all sowing date 1) produced very little infection on any variety. This could be due to poor inoculum quality or a lack of any specific virulence. Infection was generally greater on tussocks sown on sowing date 2 than sowing date 1 .

No isolates were found with specific virulence on adult plants of the varieties Atou, Val, Bouquet, Flinor, Hobbit, Gamin, West Desprez or Score.

Six isolates were found with slight specific virulence on varieties Chalk, Reso, Flanders, M Widgeon and M Fundin. There was no increase in specific virulence on these varieties of the 1974 potential field variants over the control isolates.

Ten isolates were found with specific virulence on adult plants of the varieties M Nimrod and M Huntsman. In each case virulence on M Nimrod was equal or greater than virulence on M Huntsman indicating the presence of an additional adult plant resistance factor in M Huntsman. Isolate 74/62 produced a greater mean PA value on M Huntsman than any of the other isolates. This isolate was

Table 1. Isolates used in adult plant tests

Isolate code	Variety	Region	Site
1) CONTROL ISOLATES			
69/163 *1	M Beacon	E	near Cambridge
71/368 *2	Joss Cambier	Sc	East Lothian
71/493 *3	Capta	Sc	Berwickshire
72/239 *4	M Ranger	E	Oxfordshire
72/239A	M Ranger	E	ex PBI
72/415 *5	M Ranger	Sc	East Lothian
2) 1974 POTENTIAL FIELD VARIANTS			
74/62	M Huntsman	YL	Garton-on-the-wolds
74/65	M Huntsman	SW	North Petherton
74/86	Chalk	SW	Pewsey
74/121	M Huntsman	YL	Boynton
74/122	M Huntsman	N	Croft
74/129	M Huntsman	N	Shoreswood
74/184	Chalk	E	Morley
74/208	Cappelle-Desprez	SW	Cirencester
74/284	Mega	N	Darlington
74/298	M Huntsman	EM	Wainfleet
74/329	M Huntsman	W	Abergavenny
3) OTHER ISOLATES			
74/A7	Mega	E	NIAB trial ground

notes: *1 standard isolate of race 2,3,4 (formerly 104E137)
*2 1,2,3 (formerly 41E136)
*3 1,2,3,7 (formerly 43E138)
*4 2,3,4,6 (formerly 108E173)
*5 1,2,3,6 (formerly 45E140)

Table 2. **Mean Percent Attack values for adult plants of 24 wheat varieties inoculated with 19 isolates and a mixture of P. striiformis**

Sowing date 1 = 27 October 1974, sowing date 2 = 9 December 1974.

sowing date	1	1	1	1	1	1	1	1	1	1	2	2	2	2	2	2	2	2	2	2
isolate	74/ 284	72/ 239 Con	74/ 184	71/ 368 Con	74/ 208	74/ 122	74/ A7	74/ 62	74/ 121	74/ 315	72/ 239A Con	74/ 329	69/ 163 Con	72/ 415 Con	74/ 65	74/ 129	74/ 86	71/ 493 Con	74/ 298	Mix
1. Atou	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2. Val	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0
3. Bouquet	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	0	0
4. Flinor	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5. Hobbit	0	0	0	0	0	0	0	1	0	0	0	0	1	1	1	0	0	1	0	0
6. Gamin	0	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	1	0
7. West Desprez	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0
8. Score	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	1	0	0
9. Chalk	0	0	0	2	0	1	0	0	0	0	0	0	0	4	1	2	4	1	0	2
10. Reso	0	0	0	0	0	0	0	0	0	0	0	0	1	5	3	1	1	1	0	0
11. Flanders	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0	5	1	0	0
12. Maris Widgeon	0	0	0	0	0	0	0	1	0	0	0	0	3	2	1	1	1	1	0	0
13. Maris Fundin	0	0	0	0	0	0	0	2	0	0	0	0	0	2	1	3	0	1	0	1
14. Maris Nimrod	0	0	0	0	0	2	0	15	4	4	1	4	10	9	13	15	16	7	0	9
15. Maris Huntsman	0	0	1	0	0	1	0	8	4	2	0	1	3	2	1	3	3	1	0	1
16. Maris Freeman	0	1	0	0	1	0	0	0	0	4	4	4	4	18	1	0	0	1	0	1
17. Maris Ranger	0	3	0	1	2	0	1	1	0	8	6	8	7	12	3	0	0	1	0	2
18. Kinsman	0	0	0	0	0	0	0	0	0	3	2	4	4	17	2	1	0	0	0	2
19. Maris Dove	0	0	0	0	0	0	8	0	0	0	4	4	0	6	1	0	0	0	0	0
20. Mega	0	0	0	0	0	0	0	0	0	0	0	0	16	2	3	0	2	1	11	2
21. Pride	0	0	0	0	0	0	0	0	0	0	0	0	14	0	0	0	1	0	6	0
22. Clement	0	0	0	0	0	0	0	7	0	0	0	0	0	3	0	0	4	0	0	12
23. Champlein	0	0	3	1	0	0	0	1	3	0	5	9	20	10	12	7	19	12	8	6
24. Cappelle-Desprez	0	0	0	0	0	0	0	3	0	0	2	8	23	10	10	5	13	6	3	0
maximum PA value	0	3	3	2	2	2	8	15	4	8	6	9	23	18	13	15	19	12	11	12

obtained from a severely infected field of M Huntsman in the Yorks & Lancs ADAS Region and indicates that some erosion of the adult plant resistance of M Huntsman has taken place. The amount of specific virulence on M Huntsman was less than on M Nimrod with all isolates.

Three isolates were found with specific virulence on adult plants of the variety Clement. Of these three, isolate 74/62 has shown a virulent reaction on Clement at the seedling stage although the results have been inconsistent. The other two isolates have been avirulent on Clement at the seedling stage.

Two isolates were found with specific virulence on adult plants of the varieties Mega and Pride. With both isolates virulence on Mega was greater than on Pride indicating an additional adult plant resistance factor in Pride. This specific virulence was the rarest amongst those isolates used in the test.

Four isolates were found with specific virulence on adult plants of the varieties M Freeman, M Ranger and Kinsman. This virulence appears to be of two alternative forms. Isolates 74/315, 72/239A, 74/329 and 69/163 produced a greater mean PA value on M Ranger than on M Freeman or Kinsman, whereas isolate 72/415 produced the inverse situation. There was no increase in specific virulence of the 1974 potential field variants over the control isolates.

Four isolates were found with specific virulence on adult plants of M Dove. Increased specific virulence at the seedling stage had been found on this variety with isolate 72/239A (R Johnson, personal communication) and this isolate and three others showed increased specific virulence at the adult plant stage.

Nine isolates were found with specific virulence on adult plants of the varieties Champlein and Cappelle-Desprez. Specific virulence on these two varieties is co-incidental with the sowing date effect; this is being further investigated.

A total of 7 specific virulences at the adult plant stage have been detected (one with 2 forms) indicating 7 independent adult plant resistance factors. The specific virulence for Mega was first detected in 1974 and that for Clement was first detected in these experiments.

Specific virulences appear to combine readily into physiologic races; isolate 72/415 was found to have 6 of the 7 identified virulences.

2. SEEDLING TESTS WITH 1975 ISOLATES

2.1 Samples received

205 samples of yellow rust were received at the NIAB during 1975 of which 77 have been identified. Sampling was not carried out on a random basis and therefore the frequency of specific virulences and physiologic races may not reflect that in the UK as a whole.

2.2 Virulence factor frequency

The frequency of the various virulence factors in 1975 is calculated from 68 isolates (Table 3).

Table 3. Virulence factor frequency 1970 - 1975

Virulence factor	1970	1971	1972	1973	1974	1975
1 (Chinese 166)	9	24	23	40	62	69
2 (Heine VII)	57	91	99	97	91	99
3 (Vilmorin 23)	93	97	99	98	97	100
4 (Hybrid 46)	82	71	76	59	35	35
5 (T. spelta album)	.	.	.	.	0	0
6 (Heine Kolben)	30	3	26	47	26	62
7 (Lee)	.	0	2	1	4	1
8 (Compair)	.	.	.	.	0	0
9 (Moro)	.	.	.	.	0	0
10 (Riebesel 47/51)	.	.	.	.	0	1

Virulence for Chinese 166 (necessary to infect M Templar) has continued to increase in frequency.

Virulence for Heine VII and Vilmorin 23 (necessary to infect many varieties) has remained at a high level.

Virulence for Hybrid 46 (necessary to infect M Beacon and Cardinal) has remained at a relatively low level.

Virulence for Heines Kolben (necessary to infect M Ranger, M Freeman, Kinsman and M Dove) has increased considerably in frequency and is now at its highest frequency since the Survey was started in 1967.

Virulence for Riebesel 47/51 was found for the first time in one isolate from the variety Clement from the NIAB trialground.

Virulence for T. spelta album, Compair and Moro was not found as in 1974.

2.3 Physiologic race frequency

The frequency of the physiologic races identified in 1975 is calculated from 77 isolates (including mixtures) (Table 4).

Table 4. Physiologic race frequency 1970 - 1975

Physiologic race	1970	1971	1972	1973	1974	1975
1,2,3	2	21	19	23	43	32
2,3,4	38	57	42	13	11	1
2,3,6	0	0	0	0	0	1
3,4,6	22	2	1	1	4	1
1,2,3,6	0	0	0	1	4	25
2,3,4,6	0	0	20	27	13	23
1,2,3,4,6	0	0	0	0	0	1
1,2,3,6,7	0	0	0	0	0	1
1,2,3,4,6,10 =9	0	0	0	0	0	1
other races	36	11	3	7	6	0
race mixtures	2	10	15	31	19	12
TOTAL	100	101	100	103	100	98

Race 1,2,3 (formerly 41E136) was again the most frequently identified race. It has the virulence to infect M Huntsman, M Nimrod, M Templar and many other varieties but is avirulent on M Ranger, M Freeman, Kinsman and M Dove.

Race 2,3,4,6 (formerly 108E173) was again found fairly frequently. This race is virulent on M Ranger, M Freeman, Kinsman, M Dove and many other varieties but avirulent on M Templar.

The frequency of race 1,2,3,6 (formerly 45E140) has increased in 1975 over 1974. This race is virulent on many varieties including M Huntsman, M Templar, M Ranger, M Freeman, Kinsman and M Dove.

Races 2,3,6; 1,2,3,4,6; 1,2,3,6,7 and 1,2,3,4,6,10 have not previously been identified and were isolated from the varieties M Ranger, M Huntsman, Bel and Clement respectively. The frequency of all four races was very low.

The other races identified were of approximately the same frequency as in the previous few years.

2.4 Variety-virulence factor frequency

The frequency of the individual virulence factors in samples collected from individual varieties is shown (Table 5). Frequencies have only been determined for varieties from which at least 25 isolates have been identified. The frequencies for virulence factors 0, 1, 2, 3, 4 and 6 are calculated from data collected since 1966; that for virulence 7 from data since 1971 and that for virulences 5, 8, 9 and 10 from data collected since 1974.

BROWN RUST OF BARLEY

BY B C CLIFFORD & R B CLOTHIER

Welsh Plant Breeding Station, Aberystwyth

Thirteen samples only were received from Norfolk, Oxfordshire, Devon and Dyfed reflecting the low level of brown rust of barley in 1975. Most samples were from varieties in NIAB trials and from recommended list varieties.

Two races were identified from the 9 samples successfully cultured, neither of which had been previously detected using the revised set of differentials. One race, virulent on Estate, Aim and Rika x F_1 (Baladi 16 x Rika No. 7) which carry the resistance factor Pa_3, was identified from samples of Favori and Prim from Norfolk, Maris Otter from Oxfordshire and Midas and WPBS breeding line from Dyfed. This result vindicates the genetic analysis of the Pa_3 locus carriers made by Parlevliet. The other race, capable of overcoming the resistance of CI 1243, was isolated from a mixture of races from the variety Banteng. Both of these isolates had been detected earlier in the season from field tests of the mobile nursery technique (see below). The reactions of the two races compared with the other known race detected using the new differentials are given in Table 1.

The variety Trumpf carries hypersensitive seedling resistance to the common UK races and also the newly identified Pa_3 virulent race but is susceptible in seedling tests to the CI 1243 virulent race.

Mobile Nurseries

a) Qualitative test. The field sampling using mobile nurseries that had been planned for 1975 had to be abandoned because of the infrequent occurrence of brown rust in the very dry summer. However, the sampling procedure was tested by exposing the differential varieties in artificially inoculated brown rust nurseries at the W.P.B.S. Eighteen sets of differentials were exposed resulting in the detection of the simple race BRS-74-1 (See table 1) from the majority of the tests. The CI 1243 and Pa_3 gene breaking races were detected for the first time in these tests, the former from 3 tests and the latter from 2.

b) Quantitative tests

A set of differential varieties was assembled to detect pathogen variants that were physiologically specialized on varieties with quantitative resistance. The varieties chosen were Mazurka, Abacus, Lofa Abed, Maris Mink, Aramir and Armelle. As with the situation described above, these varieties were exposed only at the WPBS.

The results indicated that the procedure adopted is not sufficiently precise to detect quantitative differences in infection. Other techniques will have to be devised to detect such variation under field conditions unless it is a very large effect.

24/3/77 BRB/EST ? 76/12
15/3/78 → MHM

Table 1. Reaction of barley brown rust races on differential varieties

Race	Gold	Estate	Cebada Capa	Aim	Gondar	Rika x F_1 (Baladi 16 x Rika No. 7)	Forrajera Klein x Rika No. 7	La Estanzuela 75A	CI 1243	CI 12201	H 2212
BRS-74-1	S	R	R	R	R	R	R	R	R	R	R
BRMN-75-16 CI 1243	S	R	R	R	R	R	R	R	S	R	R
BRMN-75-7 EST.	S	S	R	S	R	S	R	R	R	R	R

BROWN RUST OF WHEAT

B C CLIFFORD & R B CLOTHIER

Welsh Plant Breeding Station, Aberystwyth

Samples from Maris Huntsman (23) made up the majority of the 38 samples received. Other samples received were Flinor (3), Maris Nimrod (2), Maris Freeman (2), Maris Fundin (2), Atou (1), Bouquet (1), Kleiber (1), Mega (1), Sappo (1) and Score (1).

The set of differential varieties was changed for the 1975 survey as the previous set included the Recommended List varieties most of which were susceptible. These were replaced by varieties which had shown levels of resistance in W.P.B.S. field tests during 1975. The differential varieties used were Clement, Maris Ranger, Maris Hobbit, Kinsman, RPB 476/71K, Winnetou, Sterna, Val, Sappo, Maris Halberd, Maris Dove, Bastion, TW 213/13/11, TW238/62, W14820 and Kolibri. Of these, Maris Hobbit, Sterna, Sappo, Maris Halberd, TW213/13/11, TW238/62 and W14820 showed resistance as seedlings to some of the cultures tested. Clement, Winnetou and RPB476/71K were resistant to all of the cultures tested.

The race picture is not yet clear as most of the samples tested appear to be mixtures and further tests are being carried out. Field and greenhouse tests indicate that the resistance of Maris Ranger and derivatives such as Kinsman is an adult plant type and this further complicates testing procedures.

CROWN RUST OF OATS

BY B C CLIFFORD & R B CLOTHIER

Welsh Plant Breeding Station, Aberystwyth

Only two samples of crown rust were received, one of Maris Oberon from Pembrokeshire and one of Peniarth from Somerset. Race 289 was identified from the sample of Maris Oberon and Race 251 from Peniarth. Both races have previously been identified.

MILDEW OF BARLEY

By M.S. WOLFE & SUSAN E. WRIGHT

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A total of 99 samples was received, including 12 from winter barleys and two from varieties with no known resistance. As with the wheat mildew, all isolates received were treated as bulks. They were inoculated in a settling tower, and the numbers of successfully established colonies on the test varieties were counted and expressed as a percentage of those occurring on the control variety, Golden Promise. The resistance factors in the test seedlings are as follows:-

Factor	Test variety	Resistance gene	Chromosome location
R1	Weih. 37/136	'Mlh'	5?
R2	Julia	Mlg+linked 'x'	4
R3	Maris Concord	Mla6	5 (Mla)
R4	Lofa Abed	'Mlv' (2 genes)	?
R5	Sultan	'Mlas'	5 (Mla)
R6	Wing	'Mla1' (2 genes?)	5 (Mla)
R7	(Akka)	Mla9	5 (Mla)

Results from isolates obtained from varieties within each R group are presented in sequence in Table 1. All bulks were also tested on seedlings of MC 20, which carries the Mlo resistance, but no virulence was detected.

The isolate obtained from Tyra, virulent on that variety but not on Akka, indicated that Tyra possesses the Monte Cristo resistance alone, not in combination with the Lyallpur resistance as seems to be evident for Akka.

The original data summarised in Table 1 and data from other tests indicates that the majority of newer varieties which have R2 combined with some other resistance, possess Mlg, but not the linked factor 'x' on chromosome 4. This is

TABLE 1. Relative frequencies of virulences in bulk isolates from barley varieties arranged in appropriate R groups. Occasional isolates from particular varieties were non-virulent on the corresponding test seedlings: these have been omitted from the means.

		Rel. freq. of colonies on test seedlings							
	Source	R1	R2	R3	R4	R5	R6	R7	No. of isolates
R0	Proctor	22	91	34	0	11	0	0	1
R1	Astrix	5	110	48	0	20	37	0	2
	Sonja	80	55	17	6	0	47	0	2
R2	Zephyr	21	107	17	0	1	0	0	4
	Julia	47	88	50	1	31	18	0	4
R3	Midas	38	114	159	0	18	14	0	3
R4	Vada	54	58	0	65	32	0	0	2
	Varunda	6	18	2	72	7	0	0	2
	Lofa	48	34	2	23	23	54	0	2
R5	Hassan	48	63	42	0	196	2	0	3
	M. Trojan	1	23	0	12	95	2	0	2
R6	Mazurka	75	92	31	0	3	109	7	7
	Wing	55	94	18	12	10	97	0	3
	Rif	74	85	0	0	0	98	4	2
R7	Tyra	19	130	0	0	49	0	19	1
R2+4	Abacus	32	120	80	59	33	8	0	3
	Sundance	0	0*	89	94	0	0	0	1
	Universe	37	172	75	93	0	15	0	1
R2+5	Aramir	41	62	45	0	96	0	0	5
	M. Mink	55	110	71	2	110	0	0	3
	LBW 6106	14	85	34	0	78	0	0	1
R3+4	SR69/9/8/2	27	78	119	79	12	0	0	1
R4+6	Barbara	53	26	0	43	0	26	0	1

*virulent on Mlg (Goldfoil), but not on 'x', the second gene in R2

particularly evident in Table 1 for the Sundance isolate: this apparently has no virulence for R2, but in the original test showed a high frequency of virulence on the test variety Goldfoil, which possesses Mlg alone.

An isolate from SR 69/9/8/2 indicated that this host possesses the combination R3+4, whereas one from Barbara indicated that R4 is combined with R6 in the latter variety.

Although the significance is not known, it appears from Table 1 that the R2+5 varieties Aramir and Maris Mink, select pathogen populations with different characteristics. Particularly by comparing isolates from the same sites, it was evident that there was a higher frequency of V3, and probably V2, on Maris Mink than on Aramir.

Isolates obtained in the survey and from mobile nurseries were also separated into single colonies for more refined tests to try to determine differences at the seedling stage between varieties with the same resistance. For example, with the R2+4 varieties there are, broadly speaking, three categories of reaction with pathogen isolates, i.e. highly resistant, moderately resistant with necrosis, and fully susceptible. Using a range of isolates from the last two categories in separate tests, quantitative comparisons were made between R2, R4 and R2+4 varieties. Such tests revealed variation in the closeness of the reactions of the R2+4 varieties to those of the 'parent' types. The sequence was in the order, Abacus - Sundance - Universe - Georgie, where the reactions of Abacus were the most closely related to those of the R2 and R4 varieties. It is not possible at this stage to say whether this ranking may be related to any increase in infection which may occur on these varieties in the field since other unknown factors would be involved in such changes.

The use of the survey isolates as bulks rather than as single colonies confirmed the broad pattern of relationships of the populations of the pathogen selected by different resistant hosts, but it also revealed that there was considerable interference between the plots which were sampled. Some of the

evidence is summarised in Table 2; for example, there is considerable variation evident in the frequency of V1 and V6 on R3 and R4 plots at different sites.

Using the data which contributed to Table 1, but restricted to that obtained from a specific set of sites, it was possible to construct Table 3. This forms the basis of the varietal diversification strategy. It can be seen from the Table that the varieties in groups R3-R6 tend to produce relatively low frequencies of virulence, for each other. Consequently, planting varieties from each of these groups adjacent to each other, either in space or time, will tend to reduce the rate of epidemic spread. Epidemic spread will tend to be considerably more rapid if varieties within a group are grown close together, or if varieties from groups R0, R1 or R2 are included in the pattern.

TABLE 2. Relative frequencies of virulence in bulk isolates in the survey from three different sites to show variation due to plot interference at the sites

Variety Source	Site	Relative frequencies of colonies on test seedlings R1	R3	R5	R6
R2	A	47	68	55	20
	B	42	119	5	0
	C	35	111	14	8
R3	A	36	152	45	41
	B	1	193	0	0
	C	78	133	2	0
R4	A	48	2	6	109
	B	1	1	0	0
	C	12	2	14	0
R6	A	47	3	0	121
	B	93	0	0	137
	C	81	86	22	111
R2+5	A	76	30	84	0
	B	9	26	76	0
	C	43	0	95	0

A = Codford, Wilts.

B = Durham

C = Northumberland

TABLE 3. Estimated frequencies of virulence combinations on combinations of pairs of R groups. The combinations were calculated as the products of the individual virulence frequencies obtained on each R group.

Resistance pair		Estimated frequency of virulence combination on	
A	B	A	B
R2	R3	62	89
R2	R4	3	66
R2	R5	29	62
R2	R6	8	71
R3	R4	4	1
R3	R5	19	12
R3	R6	12	19
R4	R5	8	4
R4	R6	30	7
R5	R6	0	8

MILDEW OF WHEAT

BY M.S. WOLFE & SUSAN E. WRIGHT

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A total of 48 isolates was received from 15 winter wheat varieties, and 9 isolates from 7 spring wheats. Instead of the usual method of separating single colony isolates from the samples received for testing, all isolates were treated as bulks. They were inoculated in a settling tower, and the number of successfully established colonies on the test varieties were counted and expressed as a percentage of those occurring on the control variety Minister (Table 1).. The resistance factors in the test seedlings are as follows:-

Factor	Test Variety	Resistance gene	Chromosome location
R1	Axminster	Pm1	7A
R2	Ulka	Pm2	5D
R2?	Maris Nimrod	Pm2	5D
R3	Chul	Pm3b	1A
R4	Weih. M1 (≡*T. carthlicum*)	Pm4?	2A
R5	Hope	pm5	7B
R2+6	Maris Fundin	Pm2	5D
	Maris Huntsman	+Pm6	2B
	CI 12633	+?	?
R7	St 14/44	'M1r'	Rye 1R
R2+8	H.13471	Pm2	5D
		+?	4B

The main features of this part of the anaylsis are:

1. Two populations, 46 and 35, showed similar development of numerous colonies on Maris Fundin, Huntsman and CI 12633; these came from Watton (Norfolk) and Rosemaund respectively. Two other populations, from PBI, Cambridge and

TABLE 1. Colony counts on test leaf segments from inoculation of bulk mildew samples received in the survey

Variety	Isol. no.	R1	R2	R2?	R3	R4	R5	R2+6 MF	R2+6 MH	R2+6 CI	R7	R2+8
M. Huntsman	2	12	17	7	6	0	0	0	0	0	0	0
	46	0	109	69	0	0	-	74	77	46	0	0
M. Fundin	35	0	0?	42	0	0	-	62	50	71	0	0
M. Nimrod	39	40	75	26	0	0	27	0	0	0	0	2
Sappo	31	88	113	19	0	77	0	0	0	0	0	21
VPM1	4	78	16	8	0	115	0	0	0	0	0	0
Clement	51	96	0	0	0	0	0	2	0	0	101	0
Anfield	33	98	0	0	0	0	-	0	0	0	0	0
Mega	42	117	8	0	0	0	10	0	0	0	0	0
Atou	23	169	0	0	0	0	0	0	0	0	0	0
Bouquet	41	3	112	16	0	0	0	0	0	0	0	0
Cappelle	16	0	123	47	29	0	15	0	0	0	0	0
	36	70	17	7	0	0	42	1	0	0	0	27
	52	59	118	98	32	0	-	2	0	0	0	0
Champlein	34	54	71	55	0	0	0	0	0	0	0	7
Flinor	37	45	2	2	30	0	0	5	0	0	0	0
Freeman	18	0	0	0	0	0	0	0	0	0	0	0
	38	37	133	0	0	0	-	0	0	0	0	34
	53	0	0	0	0	0	81	0	0	0	0	0
M. Widgeon	44	1	2	0	0	0	16	0	0	0	0	0
Kleiber	29	0	109	79	0	0	10	5	0	1	0	0
Kolibri	30	115	1	0	0	0	138	0	0	0	0	0
Sirius	32	0	90	81	0	0	0	2	0	0	0	80
Mean		47	49	24	4	8	15		6		4	7

Aberdeen are also thought to show a high frequency of virulence for Maris Huntsman. It appears from the data that Maris Nimrod is slightly more resistant than Ulka to populations with a high frequency of R2 - virulence (V2). This, together with previous data indicates that the inheritance of resistance in CI 12633, which was used as the source of T. timopheevi resistance for many PBI varieties, is complex. There appears to be an accumulation of resistance factors in the sequence Ulka (Pm2 only); Maris Nimrod; Maris Templar and Maris Fundin; Maris Huntsman and CI 12633 (Pm2 + Pm6 + others).

2. An isolate from Sappo had virulence corresponding to R2 and R4 (i.e. V2 + 4) which indicates that the variety possesses the resistance combination of Pm2 with the T. carthlicum gene. The T. carthlicum gene is present alone in VPM1, a French variety being used for its eyespot resistance.

3. An isolate from Clement was virulent on R7 confirming that this variety possesses the rye mildew resistance gene on chromosome IR.

4. Virulence for R2 seems to be more generally common on non-R2 varieties than in previous years. This is presumably due to the selective influence of the CI 12633-based winter varieties, and Maris Dove which also possesses R2. In the 1960's, the equilibrium frequency of V2 in the pathogen population was about 10% which indicates that there was only slight selection against it. It is not surprising therefore that the introduction of R2 varieties has caused a rapid, general increase in the frequency of the corresponding virulence. In Table 1, the mean frequency of V2 on non-R2 varieties is 45%.

Other data on wheat mildew reactions were obtained from mobile nurseries containing 61 varieties or lines exposed in 17 fields or large field plots of varieties with different resistances, or susceptible. Extracts of the data are given in Tables 2-4. From Table 2 it can be seen that Maris Huntsman

TABLE 2. Mean colony counts on test seedlings exposed in mildew infected fields. The fields have been grouped into Gp.1, high relative frequency of V2 + 6 virulence, gp.2 moderate levels of V2 + 6, gp.3 low levels of V2 + 6. Gp. 1 fields were mainly large plots, including one of M. Huntsman, at PBI Cambridge.

Test seedlings	Fields Gp1	Gp2	Gp3
M. Huntsman	57	7	4
M. Templar	83	24	4
M. Fundin	91	21	5
Kinsman	93	29	7
M. Nimrod	81	29	29
Statesman	98	90	60
Durin	97	67	49
Hobbit	127	189	102
Ulka	106	28	87
M. Dove group (R2+8)	18	12	32
ELS gp (R4)	1	5	20
Sappo	1	6	14
Rye gp (R7)	9	5	18
Anfield	12	53	77
Mega	5	7	6
Axminster (R1)	28	78	56
Chul (R3)	0	0	5
Hope (R5)	10	17	29
RO gp.	54	44	74
Cappelle-Desprez	70	101	78

performs better than related varieties even in areas with high frequencies of R2 + 6 virulence. It is not certain whether this is due to background resistance in the variety of whether the frequency of Maris Huntsman-virulence is lower than that for the other varieties.

It is also evident from the lower part of the Table that most other specific virulences occur at a lower frequency in Gp1 and Gp2, than in Gp3 fields. This indicates that the newly selected pathogen populations on the CI 12633-derived material have a low flexibility, i.e. they are less well able to infect other resistant varieties than are other pathogen populations.

Table 3 gives data expressed in a similar way for fields grouped according to the frequency of V4 which the pathogen populations contain. The most obvious feature is the negative correlation with infection of the R2 + 6 varieties. The positive correlation with infection on Sappo is presumably because Sappo possesses R4. From the data on Anfield (Table 4) there is also evidence of a negative correlation with infection on R2 + 6 varieties. The apparent positive correlation between the groupings in Table 3 and 4 with respect to the ELS gp. and Anfield is not significant. It appears, therefore, that pathogen populations from R2 + 6 varieties have a relatively poor ability to attack Anfield and ELS group varieties, and vice versa. This relationship has an epidemiological value in the possible lowered rate of distribution of inoculum between the winter variety, Maris Huntsman, and the two spring varieties, Anfield and the ELS group.

TABLE 3. Mean colony counts on test seedlings exposed in mildew infected fields. The fields have been grouped according to the relative frequency of V4 in the pathogen populations.

Test seedlings	Fields			
	Gp 1	Gp2	Gp3	Gp4
ELS gp (R4)	64	27	6	0.5
M. Huntsman gp (R2+6)	0.5	5	19	41
M. Dove gp (R2+8)	40	41	21	16
Sappo	40	15	11	2
Rye gp (R7)	27	30	9	5
Anfield	102	84	48	41
Mega	8	5	12	4
Axminster (R1)	47	50	83	55
Chul (R3)	11	5	3	0
Hope (R5)	18	50	24	8
RO gp.	58	84	67	51
Cappelle-Desprez	67	82	105	75

TABLE 4. Mean colony counts on test seedlings exposed in mildew infected fields. The fields have been grouped according to the relative frequency of Anfield virulence in the pathogen populations.

	Fields			
Test seedlings	Gp1	Gp2	Gp3	Gp4
Anfield	145	92	57	17
M. Huntsman gp (R2+6)	4	8	5	55
ELS gp (R4)	21	29	11	4
M. Dove gp (R2+8)	32	22	29	21
Sappo	16	11	12	6
Rye gp (R7)	18	12	16	11
Mega	2	5	7	7
Axminster (R1)	38	84	53	30
Chul (R3)	4	3	5	0
Hope (R5)	17	12	50	13
Ro gp	110	52	73	56
Cappelle-Desprez	59	81	77	89

MILDEW OF OATS

BY R B CLOTHIER & I T JONES

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Of the fifty-nine samples received, twenty were from Scotland, twelve from Wales, eleven from the W. Midlands, and the remainder from other areas in Britain excluding Ireland. The majority of the samples were from recommended list varieties. Fourteen samples failed to culture.

A third of the samples were of varieties claimed to have major gene resistance derived from either 9065 Cn or Cc4146.

Race 2 which is avirulent on these resistance sources was only identified from one sample of Selma from Inverness.

Race 4, virulent on Mostyn, was identified from more than half of the samples received. This has been the most prevalent race identified, from material sent in, over the last four years.

Race 3, which overcomes the resistance derived from Cc4146 (in Maris Tabard and Nelson) but not 9065 Cn, was identified in eight samples from the south and east of England, Wales and Scotland. It was identified in four samples from Maris Tabard, two samples from Nelson and in one sample of Mandarin and Peniarth.

Eight samples were found to be race 5, virulent on 9065 cn and Cc 4146, five from Scotland, on Margam (2 samples), Maris Oberon, Maris Tabard and Nelson, two samples on Maris Oberon and Maris Tabard from Somerset, and on Maris Tabard from Pembrokeshire.

It can be expected that races 3 and 5 will increase in frequency due to varieties with resistance derived from Cc 4146 becoming more widely grown.

Mobile nurseries were to be exposed in crops of oat but this was not carried out because of the low incidence of oat mildew in 1975.

A small scale test was carried out in trial material at the W.P.B.S. but the inoculum level was so low that a uniform inoculation was not achieved.

RHYNCHOSPORIUM OF BARLEY

BY R B CLOTHIER

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Sixty samples were received, all from varieties in NIAB trials or on the recommended list except one, a sample designated as 698C which failed to culture. A total of six samples failed to culture.

The majority of the samples received were from varieties sent in from trial centres.

Twenty six of the samples tested were identified as race U.K.1 and twenty-eight samples as race U.K.2.

Race U.K.2 was found commonly on the winter varieties which carry resistance to race U.K.1. It was also detected on the spring variety Arwelle, also resistant to race U.K.1.

Quantitative assessments carried out by Habgood (Welsh Plant Breed. Stn. Ann. Rpt. for 1974, p.37) have detected a culture of Rh.secalis specifically adapted to the susceptible cultivar Maris Otter. The demonstration of this type of variation, although probably not of any consequence in relation to Maris Otter, is of significance in relation to varieties such as Proctor which have a more acceptable level of partial resistance.

VARIETAL DIVERSIFICATION: YELLOW RUST OF WHEAT AND BARLEY MILDEW

The following two papers were sent by the Chairman of the Physiologic Race Survey Committee to the testing authorities in England & Wales, Scotland and Northern Ireland, and to the Agricultural Development & Advisory Service.

The information in these papers is based on the papers on yellow rust of wheat and barley mildew in this Report.

Information supplied by the National Institute of Agricultural Botany, Cambridge . and approved by the Physiologic Race Survey Committee (Cereal Pathogens).

VARIETAL DIVERSIFICATION : YELLOW RUST OF WINTER WHEAT

Growing more than one winter wheat variety on a farm can reduce the risk of severe yellow rust infections. It is important to choose varieties to grow together that have different resistance factors so that any new race or variant adapted to one variety is unlikely to be able to attack the others.

Winter wheat varieties grouped according to their adult plant resistance factors

1	2	3	4	5
Atou	Maris Huntsman	Kinsman	Mega	Cappelle-Desprez
Bouquet	Maris Nimrod	Maris Freeman		Champlein
Chalk	Maris Templar*	Maris Ranger		
Flanders				
Flinor				
Maris Fundin				
Maris Widgeon				
Val				

* resistance factor slightly different from other varieties in group 2

notes for selecting varieties to grow together:

1) Grow at least one variety from group 1 as variants adapted to these varieties have not yet been found. All the varieties in group 1 can be grown together.

2) Do not grow together varieties from within group 2, 3 or 5.

3) Do not grow a large acreage of either variety in group 5 as many variants are adapted to these varieties.

Information supplied by the Plant Breeding Institute, Cambridge and approved by the Physiologic Race Survey Committee (Cereal Pathogens).

VARIETAL DIVERSIFICATION : BARLEY MILDEW

It is generally accepted that the use of single varieties over large areas in successive years is one of the most important factors enabling the major leaf pathogens to rapidly overcome the disease resistance of the varieties. Diversification among the varieties grown has therefore been recommended to try to reduce this effect by slowing the spread of disease.

Varietal diversification has little value, of course, if the varieties involved have identical disease resistance factors. The first stage in a rational programme of varietal diversification, therefore, is to group all of the varieties according to the particular resistance which each carries. This is defined for barley mildew by resistance groups 0 - 6 in the Table.

The second stage in determining the best diversification policy is to find whether certain combinations of the resistance groups are better than others in reducing the rate of disease spread. This has been worked out for barley mildew and it is now known that the infection produced on varieties of any of the groups 3 - 6 provides relatively little inoculum able to infect any of the varieties in the other groups of 3 - 6. In other words races of the pathogen with combinations of virulence for host groups 3 - 6 are relatively uncommon. This is not true for any combinations involving groups 0 - 2, or between these groups 3 - 6.

As an example, we observed disease progress on a field of Mazurka, resistant in one year, which was replanted with the same variety in the same field in a second year. Rare infections built up on volunteer Mazurka plants during the intervening winter so that the second Mazurka crop became heavily infected. In the second year, a field of Sultan was planted next to the heavily infected Mazurka, but it remained moderately resistant throughout the season. The reason was that races of the pathogen able to attack both varieties were rare so that most of the mass of spores generated by the Mazurka plants could not infect the Sultan crop. If the field position of the two varieties had been exchanged in the second year, little infection would have developed on either crop.

The diversification scheme will be updated as necessary each season. The recommendations can help to reduce the risk of early and severe epidemic increase, but in order to obtain maximum disease control, advice should be sought from ADAS for the most efficient use of fungicidal control to integrate with varietal diversification.

The barley varieties are divided into groups according to the different mildew resistances which they contain. In order to reduce the mildew risk, spring or winter varieties within a group should not be grown adjacent to each other, either in space or time.

The most useful combinations of varieties to reduce mildew levels can be made up from groups 3, 4, 5 and 6: the best combination is between groups 5 and 6. Group 2 varieties should only be used with varieties not marked*.

Mildew resistance groups

	0	1	2	3	4	5	6
Winter barley	Hoppel Maris Otter Mirra	Malta Senta Sonja Astrix*	-	-	-	Maris Trojan	-
Spring barley	Clermont Freegold Golden Promise Proctor	-	Armelle Berac Imber Julia Mosane Zephyr	Midas	Lami Lofa Abed Vada Varunda Abacus* Georgie* Sundance* Universe*	Hassan Aramir* Maris Mink*	Ark Royal Mazurka Tern Wing Tyra**

notes

* resistance in these varieties is combined with resistance similar to that found in group 2 varieties.

** different from group 6 resistance, but with similar relationships to group 6.