# PHYSIOLOGIC RACE SURVEY
# (CEREAL PATHOGENS)

## 1976 Annual Report

# PHYSIOLOGIC RACE SURVEY (CEREAL PATHOGENS)

Chairman: Dr G D H Bell CBE FRS

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

## 1976 ANNUAL REPORT

(not for publication)

Issued by the Physiologic Race Survey Committee

Cambridge, England

May 1977

PHYSIOLOGIC RACE SURVEY COMMITTEE MEMBERS 1976 - 1977

| | |
|---|---|
| Dr G D H Bell | formerly Plant Breeding Institute, Cambridge |
| Mrs F G A Bennett | Plant Breeding Institute, Cambridge |
| Mr P Byford | National Institute of Agricultural Botany, Cambridge |
| Dr A J Carr | Welsh Plant Breeding Station, Aberystwyth |
| Dr B C Clifford | Welsh Plant Breeding Station, Aberystwyth |
| Dr D A Doling | RHM Research Ltd, High Wycombe |
| Dr J K Doodson | National Institute of Agricultural Botany, Cambridge |
| Mr C S Elliott | National Institute of Agricultural Botany, Cambridge |
| Dr J Gilmour | East of Scotland College of Agriculture, Edinburgh |
| Dr J D Hayes | Welsh Plant Breeding Station, Aberystwyth |
| Mr J E E Jenkins | Agricultural Development & Advisory Service |
| Dr R Johnson | Plant Breeding Institute, Cambridge |
| Mr E Jones | Welsh Plant Breeding Station, Aberystwyth |
| Dr J G Kay | British Association of Plant Breeders |
| Dr J E King | Plant Pathology Laboratory, Harpenden |
| Professor R K McKee | Department of Agriculture, Northern Ireland |
| Dr R H Priestley | National Institute of Agricultural Botany, Cambridge |
| Mr M J Richardson | Department of Agriculture & Fisheries for Scotland |
| Professor R Riley | Plant Breeding Institute, Cambridge |
| Dr P A Round | RHM Research Ltd, High Wycombe |
| Dr J Rowe | National Institute of Agricultural Botany, Cambridge |
| Dr P S Wellington | National Institute of Agricultural Botany, Cambridge |
| Dr M S Wolfe | Plant Breeding Institute, Cambridge |
| Mrs S Wright | Plant Breeding Institute, Cambridge |

CONTENTS



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 cultivar Rothwell Perdix. This cultivar had previously been resistant to yellow rust and the epidemic was caused by a previously unknown virulence factor combination (physiologic race).

The Survey is supported financially by the Ministry of Agricultre, Fisheries & Food and by the Agricultural Research Council.

## OBJECTIVES

The principal objective is the detection of new virulences and virulence combinations in the UK population of cereal pathogens.
Secondary objectives include monitoring the frequency of individual virulences and virulence combinations, evaluating the compatibility of virulences with one another, measuring the effect of changes in cultivar on the pathogen population and providing information for cultivar diversification schemes.

## OPERATION

Each spring a list of cereal cultivars from which disease samples are requested 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 virulence identification. Increased virulence is detected on seedlings or detached leaf segments inoculated under controlled environment conditions. Recently tests involving adult plants grown in Polythene tunnels have been introduced for detecting increases in adult plant virulence in yellow rust and brown rust of wheat.

## RESULTS

An Annual Report (such as this) is produced each May and about 200 copies are sent to MAFF advisors, NIAB personnel, BAPB members, ARC breeding Institutes, Universities and Colleges, and overseas Institutes.

The Annual Report contains papers from the three testing centres about the diseases surveyed giving details of the virulences identified. Virulence factor frequencies are given for some of the diseases.

UTILIZATION OF RESULTS

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

1) Isolates containing new virulence factors are used by the NIAB to evaluate the resistance of cereal cultivars under trial. There are many instances of cultivars not being recommended by the NIAB because of their susceptibility to isolates containing new virulences.

2) These isolates are also distributed to plant breeders who use them to select new lines with effective forms of resistance. There are many instances of lines being rejected by breeders because of their susceptibility to isolates containing new virulences.

3) Advisory pathologists use the diversification schemes to recommend to farmers those cultivar combinations that minimise the risk of severe infections.

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

Much of the benefit resulting from 1) and 2) is not realised by farmers and consumers as they are not aware of the extremely susceptible lines and cultivars that are rejected by breeders and the NIAB.

FUTURE DEVELOPMENTS

In order to realise its objectives the Survey actively promotes research projects at the three testing centres. 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 increased adult plant virulence and new numerical techniques.

## SUMMARIES

A short summary of each paper is given.

### Yellow rust of wheat

The frequency of Chinese 166 virulence (V 1) increased in 1976 continuing the trend started in 1971. The frequency of Hybrid 46 virulence (V 4) and Heine Kolben virulence (V 6) decreased in 1976.
Compair virulence (V 8) was detected in the United Kingdom population for the first time in 1976. It has not previously been detected in any North West Europe population.
Adult plant tests have confirmed the increased virulence for Maris Huntsman and Maris Nimrod (V 1,2,3,13) described in the 1975 PRS Annual Report. Increased adult plant virulence for Hobbit and Score (V 2,3,4,14) was detected in 2 isolates from inoculated plots. This virulence combination was not detected in any natural population in 1976.
An interaction in adult plant virulence between Kinsman and Maris Ranger & Maris Freeman was detected. All three cultivars probably contain the seedling resistance R 6 combined with different adult plant resistances.
No increased adult plant virulence was detected on Little Joss or Yeoman. The resistance of these two cultivars has remained effective for over 50 years and is being used as a possible source of durable resistance.
No increased adult plant virulence was detected for the commercial cultivars Atou, Maris Widgeon, Flinor, Val, Flanders and Gamin.
No samples were received from the European Yellow Rust Trials Project sites.

### Yellow rust of barley

Combined virulence for Astrix and Sultan (V 1,5) was extremely frequent in the 1976 population, as has been the case since 1972. It is virulent on most spring and winter cultivars with the exception of Mazurka and Varunda. Virulence for Bigo (V 2), Varunda (V 3) and Mazurka (V 4) were not identified in 1976 although they were identified at a low frequency in 1975. This may be due to the much smaller number of samples tested in 1976.

### Brown rust of barley

Twelve isolates were successfully cultured of which 6 carried virulence to gene $Pa_3$ and 4 carried virulence to the CI 1243 resistance. One culture was identified which combined these virulences.
A new standard set of international differential cultivars was used together with a supplementary set of UK differential cultivars. These changes follow

an agreement reached by barley brown rust workers at the 1976 Cereal Rust Conference at Interlaken, Switzerland.

Brown rust of wheat

Seedling tests at WPBS have indicated that cultivars can be placed in 4 different groups based on their patterns of resistance. Comparative seedling and adult plant tests at NIAB have demonstrated the presence in cultivars of 2 overall resistances (R 1 and R 2) and four adult plant resistances (R 3 - R 6). A number of cultivars also exhibited 'slow rusting' characterised by a susceptible reaction type at both growth stages with a relatively small percent leaf area infection at the adult plant stage.

A mixture of four isolates was compared with the individual isolates in an adult plant test at NIAB. The results indicated that all the specific virulences present in the individual isolates were also expressed in the isolate mixture.

Tests on the seedling resistance of Maris Fundin at WPBS have shown that the resistance was fully expressed at 25/20$^{\circ}$C and 20$^{\circ}$C constant, but the plants were fully susceptible at 15/10$^{\circ}$C.

Crown rust of oats

No samples were received in 1976

Mildew of barley

All isolates were again tested quantitatively as bulk samples. It was confirmed that Maris Mink has a third resistance factor additional to the two also present in varieties such as Aramir (R2+5). Mazurka was found to have the resistance combination R2+6, rather than R6 only, as, for example, in Wing. Tyra, derived from Monte Cristo, has one gene in common with Akka, derived from the same source, but both varieties have other resistance genes not common to each.

Quantitative analyses revealed specific adaptation of the pathogen for varieties within each resistance group, which correspond closely with field observations of the relative susceptibility of the varieties. It was also found that isolates with combined virulence are generally not as virulent on varieties which possess separately the corresponding resistances, as simple isolates obtained from varieties with the single resistances.

In the diversification scheme, there was no apparent major change in the choice of best variety combinations to minimise mildew spread.

Mildew of wheat

All isolates were treated as in 1975 but were tested on an expanded set of differentials. It was possible to divide most of the varieties from which samples were received into R groups. The largest group was R0 but this included varieties which were obviously selecting different pathogen populations. Although virulence for R2 became widespread in the population, virulence for Maris Huntsman was still rare on non-selective varieties. The data suggests that Maris Huntsman virulence had a lower level of adaptation on its own host than any of the other virulences tested. Virulence for the rye mildew resistance (R7) was more common than in 1975. A new group, R9, was formed, into which Flanders and Mega were placed. Analysis of three isolates from RPB 6/73 placed this variety in the Sappo group. Similarly, cebeco 180 was placed in the Maris Dove group. One isolate each from Walter and Timmo indicated that these varieties have at least three different resistances.

Mildew of oats

Races 2, 3, 4 and 5 were identified in the thirty one samples successfully cultured. All seedling resistance factors in commercial cultivars have now been overcome. Race 5, which has the widest spectrum of virulence attacking both the Cc 4146 resistance (in Maris Oberon, Maris Tabard, Nelson and Margam) and the 9065 Cn resistance (in Mostyn), has become the most prevalent race. Race 5 was detected for the first time in samples from Scotland and Eire.

Rhynchosporium of barley

The majority of samples came from Scotland, Ireland and Northern England. Seven samples were identified as race UK 2, 29 were identified as race UK 1.

# YELLOW RUST OF WHEAT

R H Priestley & P Byford

National Institute of Agricultural Botany, Cambridge

## 1) ISOLATES USED IN VIRULENCE TESTS

### 1.1 1976 isolates

A total of 76 samples was received. These had been collected from Maris Huntsman (20 samples), Clement (4), Sportsman (4) and 35 other cultivars. Isolates were made from 53 samples, the remainder failed to sporulate on seedlings of Sappo.

Seedling virulences have been identified in 52 of the 53 isolates. Nine of the isolates (from sites with greater than expected disease on specific cultivars) have been multiplied for adult plant virulence tests in Polythene tunnels in 1977.

### 1.2 1975 isolates

Adult plant virulences have been identified in 25 isolates using the Polythene tunnel system. The isolates comprised nine control isolates (from previous years) and 16 isolates from sites with greater than expected disease. Details of the isolates are given in Table 1. Isolates 72/239, 73/A7 and 73/143 were included in the test but the results have not been included as there was evidence of a loss in virulence in comparison with their past performance.

## 2) VIRULENCE NUMBERING SYSTEM

### 2.1 Addition of adult plant virulences

The virulence numbering system has been extended to include virulence for four adult plant resistances (R11 - R14). Details of the resistance factors are given in Table 2. The resistance factor in Riebesel 47/51 is now designated R 9 and that in Moro designated R 10. This is the reverse of designations given in previous Annual Reports.

Table 1. Isolates used in adult plant Polythene tunnel tests

| Isolate code | Variety | Region | Site |
|---|---|---|---|
| 1) Control isolates | | | |
| 69/163 | Maris Beacon | E | near Cambridge |
| 71/26 | Joss Cambier | SW | Ashbury |
| 71/368 | Joss Cambier | Sc | East Lothian |
| 72/415 | Maris Ranger | Sc | East Lothian |
| 74/62 | Maris Huntsman | YL | Garton-on-the-Wolds |
| 74/86 | Chalk | SW | Pewsey |
| 74/129 | Maris Huntsman | N | Shoreswood |
| 74/298 | Maris Huntsman | EM | Wainfleet |
| 74/329 | Maris Huntsman | W | Abergavenny |
| 2) 1975 isolates | | | |
| 75/19 | Maris Huntsman | E | Little Eversden |
| 75/38 | Maris Ranger | SW | Hartbury |
| 75/39 | Maris Huntsman | SW | Taunton |
| 75/103 | Kinsman | EM | Kirton |
| 75/106 | Mega | EM | Holbeach |
| 75/109 | Kinsman | WM | Harper Adams |
| 75/114 | Maris Huntsman | EM | Frithville |
| 75/146 | Reso | SE | Wye |
| 75/154 | Cappelle-Desprez | Sc | SPBS |
| 75/166 | Kinsman | E | Trumpington |
| 75/167 | Clement | E | Terrington |
| 75/178 | Flanders | N | Buston Barns |
| 75/189 | Maris Fundin | EM | North Cotes |
| 3) Other isolates | | | |
| 75/27 | plot of Hobbit inoculated with WYR 72/23 at PBI | | |
| 75/160 | plot of Hobbit inoculated with WYR 72/23 at Sutterton | | |
| 75/A1 | tussock of Clement inoculated with 74/62 at NIAB | | |

Table 2. Sequentially numbered resistance factors

| Resistance factor | Test cultivar | Type of resistance* |
|---|---|---|
| R 1 | Chinese 166 | overall |
| R 2 | Heine VII | overall |
| R 3 | Vilmorin 23 | overall |
| R 4 | Hybrid 46 | overall |
| R 5 | Triticum spelta album | overall |
| R 6 | Heine Kolben | overall |
| R 7 | Lee | overall |
| R 8 | Compair | overall |
| R 9 | Riebesel 47/51 | overall |
| R 10 | Moro | overall |
| R 11 | Joss Cambier | adult plant |
| R 12 | Mega | adult plant |
| R 13 | Maris Huntsman | adult plant |
| R 14 | Hobbit | adult plant |

* overall resistance is effective at both seedling and adult plant growth stages; adult plant resistance is ineffective at seedling growth stages (after Zadoks, 1961).

---

## 2.2 Common names for virulence combinations

The more important virulence combinations have been given common names based on a cultivar with which they are compatible. This is not necessarily the cultivar from which the particular virulence combination was first isolated.

Some of the virulences in the more complex combinations may be unnecessary for compatibility. This particularly applies to V 2 and V 3. This cannot be investigated until isolates with simpler virulence combinations have been obtained. The designations of some of the virulence combinations may therefore have to be revised when more information is available.

## 3) CHANGES IN VIRULENCE FREQUENCY

The frequency of critical virulences and virulence combinations in the United Kingdom population in 1975 and 1976 is given in Table 3. Sampling was not carried out on a random basis and therefore the frequencies may not reflect those in the UK as a whole.

The frequency of combinations involving only seedling virulences have been determined from standard seedling reaction type data. The frequency of combinations involving adult plant virulences has been calculated from the number of isolates with a two-factor residual greater than 5.0 (underlined in Table 4) expressed as a percentage of the 13 1975 isolates (Table 2).

### 3.1 Chinese 166 virulence (V 1) & Hybrid 46 virulence (V 4)

The frequency of V 1 increased in 1976 continuing the trend started in 1970 - 71 (see Table 3, 1975 Annual Report). The frequency of V 4 decreased in 1976 again illustrating the reciprocal relationship between these two virulences. Evidently R 1 and R 4 are not allelic as a breeding line containing both has been produced at the Plant Breeding Institute, Cambridge.

### 3.2 Heine VII virulence (V 2) & Vilmorin 23 virulence (V 3)

The frequency of V 2 and V 3 have remained close to 100 per cent in 1976. The frequency of both virulences has been over 90 per cent since 1971 (see Table 3, 1975 Annual Report). This is almost certainly the result of R 2 and R 3 being present in most commercial varieties.

### 3.3 Heine Kolben virulence (V 6)

The frequency of V 6 decreased from 62 per cent in 1975 to only 4 per cent in 1976. The frequency of V 6 has been particularly variable over the last 7 years (Table 3, 1975 Annual Report). This could be the result of R 6 being environmentally sensitive under seedling test conditions. The relationship between R 6 and the cultivars Maris Ranger, Maris Freeman and Kinsman is being investigated.

### 3.4 Compair virulence (V 8)

V 8 was detected in the United Kingdom population for the first time in 1976. The isolate (76/15) was collected from Clement at Boston, Lincolnshire (EM Region).

Table 3. Frequency of critical virulences and virulence combinations

| | Common name | Frequency 1975 [1] | Frequency 1976 [2] |
|---|---|---|---|
| V 1 | Chinese 166 virulence | 69 | 92 |
| V 2 | Heine VII virulence | 99 | 100 |
| V 3 | Vilmorin 23 virulence | 100 | 100 |
| V 4 | Hybrid 46 virulence | 35 | 12 |
| V 5 | T. spelta album virulence | 0 | 0 |
| V 6 | Heine Kolben virulence | 62 | 4 |
| V 7 | Lee virulence | 1 | 0 |
| V 8 | Compair virulence | 0 | 2 |
| V 9 | Riebesel 47/51 virulence | 1 | 6 |
| V 10 | Moro virulence | 0 | 0 |
| V 1,2,3 | Maris Templar virulence | 70 | 86 |
| V 1,2,6 | Rothwell Perdix virulence | 33 | 0 |
| V 2,3,4 | Maris Beacon virulence | 30 | 10 |
| V 2,3,11 | Joss Cambier virulence | . | . |
| V 1,2,3,7 | Tommy virulence | 1 | 0 |
| V 1,2,3,13 | Maris Huntsman virulence [4] | 23 [3] | . |
| V 2,3,4,9 | Clement virulence | 1 | 4 |
| V 2,3,4,12 | Mega virulence [5] | 8 [3] | . |
| V 2,3,4,14 | Hobbit virulence [6] | 0 [3] | . |
| ? | Maris Ranger virulence [7] | 0 [3] | . |
| ? | Kinsman virulence | 31 [3] | . |

notes

. not tested

1) from seedling tests with 68 isolates

2) from seedling tests with 52 isolates

3) from adult plant tests with 13 isolates

4) also increased virulence on Maris Nimrod

5) also increased virulence on Pride

6) also increased virulence on Maris Bilbo, Score, Bouquet and West Desprez

7) also increased virulence on Maris Freeman

Table 4 1976 YELLOW RUST OF WHEAT POLYTHENE TUNNEL TEST DATA

Sowing date: 10 - 11 November 1975. Inoculation dates: 23 - 27 February and 16 March 1976. Assessment dates: 6 May, 18 May, 2 June and 15 June 1976.

Values are mean percent leaf area infected from 3 replicate tussocks assessed on 4 dates.
Underlined values indicate increased specific virulence of at least 5 percent leaf area infected (from two-factor residuals). (Residual = O-E)
Showing an interaction - departure from linear model

| Isolate / Cultivar | A | B | C | Mean |
|---|---|---|---|---|
| A | 10 | 20 | 30 | 20 |
| B | 20 | 30 | 40 | 30 |
| C | 30 | 40 | 50 | 40 |
| Mean | 20 | 30 | 40 | (40) |

R = resistant seedling reaction in controlled environment test.

Data for isolates 72/239, 73/A7 and 73/143 omitted owing to changes in virulence.

| seedling virulences | 1,2,3 (= 41 E 136) | | | | | | | | | | | 2,3,4 (= 104 E 137) | | | | | 1,2,3,6 (= 45 E 140) | 2,3,4,6 (= 108 E 141 or 108 E 173) | | | | | | | 2,3,4,9 (-) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| isolate number | 74/62 | 75/38 | 75/178 | 75/154 | 74/86 | 74/129 | 75/106 | 71/368 | 75/146 | 75/167 | 75/19 | 69/163 | 71/26 | 75/27** | 75/160 | 75/189 | 72/415 | 75/166 | 75/114 | 75/39 | 75/109 | 74/329 | 75/103 | 74/298 | 75/A1 |
| 1. Atou | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2. Maris Widgeon | 2 | 2 | 1 | 3 | 3 | 1 | 4 | 2 | 3 | 2 | 0 | 2 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 2 | 2 | 1 | 1 | 1 | 1 |
| 3. Flinor | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4. Val | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5. Flanders | 1 | 1 | 0 | 2 | 2 | 0 | 3 | 3 | 2 | 2 | 1 | 2 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 |
| 6. Gamin | 0 | 0 | 0 | 0 | 0 | OR | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 3 | 2 | 1 | OR | 0 | 0 | 2 | 1 | 1 | 1 | 2 | 0 |
| 7. Kador | 4 | 2 | 1 | 2 | 3 | 2 | 4 | 4 | 1 | 2 | 1 | 2 | 1 | 6 | 5 | 0 | 3 | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 0 |
| 8. Little Joss | 1 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 |
| 9. Yeoman | 5 | 2 | 2 | 2 | 2 | 1 | 3 | 2 | 2 | 1 | 0 | 1 | 1 | 2 | 1 | 0 | 0 | 1 | 2 | 3 | 3 | 2 | 1 | 0 | 0 |
| 10. Mega | 1 | 0 | 1 | 2 | 2 | 2 | 1 | 2 | 1 | 2 | 0 | 9 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 7 | 6 | 0 |
| 11. Clement | 3R | OR | OR | 4R | 4R | 1R | OR | OR | OR | OR | OR | OR | 7R | OR | 2R | OR | 1R | OR | 1R | 2R | OR | OR | 1R | OR | 55 |
| 12. Hobbit | 1 | 1 | 0 | 2 | 1 | 1 | 2 | 3 | 1 | 1 | 0 | 2 | 0 | 37 | 12 | 0 | 1 | 0 | 1 | 0 | 1 | 3 | 2 | 0 | 0 |
| 13. Score | 0 | 2 | 0 | 6 | 3 | 3 | 3 | 12 | 2 | 1 | 1 | 2 | 1 | 45 | 13 | 0 | 4 | 1 | 2 | 1 | 0 | 5 | 1 | 1 | 1 |
| 14. Bouquet | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 2 | 1 | 0 | 1 | 0 | 5 | 1 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| 15. West Desprez | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 0 | 7 | 2 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 |
| 16. Maris Ranger | 1 | OR | OR | 1R | OR | 1R | OR | 1R | 0 | OR | OR | 4R | 1R | OR | OR | OR | 10 | 1 | 1 | 5 | 4 | 9 | 7 | 1R | OR |
| 17. Maris Freeman | 1R | OR | OR | OR | OR | OR | OR | OR | 1R | OR | OR | 5R | 1R | OR | OR | OR | 12 | 1 | 1 | 5 | 4 | 5 | 6 | 1R | OR |
| 18. Kinsman | 3R | 1R | 2R | 9R | 1R | 2R | 3R | 2R | 6R | 1R | OR | 4 | 0 | 0 | 4R | OR | 2 | 9 | 10 | 15 | 17 | 4 | 7 | 7 | OR |
| 19. Maris Nimrod | 18 | 19 | 21 | 16 | 8 | 11 | 10 | 9 | 9 | 5 | 2 | 8 | 2 | 4 | 2 | 3 | 6 | 8 | 13 | 13 | 10 | 3 | 3 | 8 | 2 |
| 20. Maris Huntsman | 8 | 7 | 5 | 10 | 3 | 2 | 6 | 3 | 4 | 2 | 2 | 4 | 2 | 2 | 2 | 1 | 1 | 4 | 5 | 5 | 4 | 1 | 1 | 4 | 1 |
| 21. Sportsman * | 8 | 5 | 2 | 3 | 1 | 2 | 3 | 2 | 1 | 1 | 0 | 1 | OR | OR | 1 | OR | 0 | 0 | 1 | 0 | OR | 0 | 0 | 1 | 0 |
| 22. Maris Fundin | 8 | 6 | 4 | 4 | 0 | 2 | 2 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 3 | 3 | 5 | 1 | 1 | 2 | 0 |
| 23. Grenade * | 3 | 5 | 3 | 7 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | OR | OR | 0 | 0 | 0 | 1 | 1 | 0 | OR | 0 | 2 | 1 |
| 24. Champlein | 5 | 3 | 2 | 7 | 6 | 3 | 14 | 13 | 7 | 4 | 4 | 10 | 2 | 6 | 6 | 3 | 11 | 1 | 3 | 8 | 4 | 7 | 6 | 6 | 1 |
| 25. Cappelle-Desprez | 4 | 3 | 2 | 5 | 5 | 2 | 9 | 8 | 6 | 4 | 2 | 6 | 2 | 3 | 4 | 1 | 4 | 1 | 1 | 3 | 4 | 4 | 5 | 3 | 1 |
| 26. Hawk | 4 | 11 | 3 | 17 | 19 | 13 | 13 | 8 | 8 | 6 | 5 | 12 | 6R | 1R | 11 | 0 | 15 | 3 | 3 | 4 | 1R | 3 | 3 | 1 | 1 |

* flag leaf more susceptible than lower adult leaves
** PBI isolate number

Other seedling virulences present were V 2, V 3, V 4 and V 9. Tests to identify adult plant virulences have not yet been carried out.

R 8 is an overall resistance factor derived from Aegilops comosa. V 8 has not previously been detected in North West Europe populations. It has been common in the Mediterranean and Asiatic regions where A. comosa is indigenous.

3.5 Riebesel 47/51 virulence (V 9) & Clement virulence (V 2,3,4,9)

V 9 was first detected in the United Kingdom population in 1974 (see 1975 Annual Report). Tests with isolate 75/A1 have shown it to be virulent on both seedlings and adult plants of Clement. The high level of infection (Table 4) indicates that the background resistance of Clement is relatively small confirming the observations in Holland (R Stubbs, personal communication).

Riebesel 47/51 is a chromosome substitution line possessing chromosome 1R from Secale cereale (rye) in place of 1B, and is a parent of Clement. Clement probably possesses additional resistance factors as Heine VII (R 2) and Cleo (R 2,?) are present in its pedigree. At present Clement virulence is being designated V 2,3,4,9 as this is the simplest combination found with virulence for Clement.

3.6 Maris Templar virulence (V 1,2,3)

Virulence for Maris Templar was found very frequently in 1976. Tests in Polythene tunnels in 1974 have shown that this cultivar has relatively little background resistance.

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

The 1976 Polythene tunnel test data has clarified the position regarding adult plant virulence for Maris Huntsman and Maris Nimrod. Four isolates (74/62, 75/38, 75/178 and 75/154) showed increased specific virulence for Maris Nimrod (Table 4) and also produced relatively large percent leaf area infected values on Maris Huntsman. Isolate 74/62 also produced a similar high value on Maris Huntsman in tests in 1975 (see Table 2, 1975 Annual Report).

The increase in virulence for both Maris Huntsman and Maris Nimrod is relatively small which makes the qualitative determination of virulence presence difficult. Maris Huntsman appears to have an additional isolate non-specific resistance not present in Maris Nimrod.

Isolate 74/62 also produced a relatively high percent leaf area infection on Sportsman and Maris Fundin.

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

This virulence was first detected in isolate 69/163 in Polythene tunnel tests carried out in 1974. Previous tests have shown that isolates with increased virulence for Mega also show a similar increase on Pride.

The frequency of Mega virulence has remained fairly low.

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

Virulence for Hobbit and Score was detected in 2 isolates (75/27 and 75/160) from inoculated plots. It was not detected in any natural population in the UK in 1975. The results indicate that Hobbit and Score have relatively little background resistance. Isolate 75/27 also produced an increased amount of disease on Bouquet and West Desprez.

The high level of infection on Hobbit confirms the observations made by Dr Johnson at the Plant Breeding Institute, Cambridge in 1975.

Previous tests have shown that isolates virulent on Hobbit are also virulent on Maris Bilbo.

3.10 Maris Ranger, Maris Freeman & Kinsman virulence (V ?)

The data in Table 4 indicates that isolate 72/415 has increased specific virulence for Maris Ranger and Maris Freeman whereas isolates 75/166, 75/114, 75/39 and 75/109 have increased specific virulence for Kinsman. This interaction has not been detected previously. The results indicate that Maris Ranger and Maris Freeman have an adult plant resistance factor 'x' and Kinsman a different factor 'y'. Further work is being carried out to confirm these results.

The frequency of Kinsman virulence was relatively high in 1975. Two of the isolates with Kinsman virulence were collected from fields of Kinsman with moderately severe infections (75/109 from Harper Adams and 75/166 from Trumpington).

3.11 Virulence for Champlein and Hawk

Increased virulence for Champlein and Hawk was found (Table 4). This is being further investigated.

3.12 Virulence for Little Joss and Yeoman

None of the isolates tested showed increased adult plant virulence for Little Joss or Yeoman. There is evidence that the resistance of these two cultivars has remained effective for over 50 years.

3.13 Virulence for other cultivars

No increased adult plant virulence was detected for Atou, Maris Widgeon, Flinor, Val, Flanders or Gamin.

Isolates 75/27 and 75/160 produced a slightly greater infection on Gamin than other isolates. Isolates 74/62, 75/38, 75/178 and 75/154 produced a slightly greater infection on Grenade than did other isolates.

Adult plant virulence for Cappelle-Desprez was variable.

4) EQUIVALENT WORLD AND EUROPEAN PHYSIOLOGIC RACE NUMBERS

The following are equivalent:

| World and European race number | virulence combination |
|---|---|
| 41 E 136 | V 1,2,3 |
| 37 E 132 | V 1,2,6 |
| 104 E 137 | V 2,3,4 |
| 45 E 140 | V 1,2,3,6 |
| 108 E 141 or 108 E 173 | V 2,3,4,6 |

Virulence combinations involving virulence for Joss Cambier (R 11), Mega (R 12), Maris Huntsman (R 13) and Hobbit (R 14) cannot be differentiated on the World and European system.

Appendix: Identification of isolates from the UK and Eire section of the International Survey of Factors of Virulence of *P. striiformis*

## Identification of samples

No samples were received during the 1975 - 76 season.

## Data from trap nursery sites

Seed of 84 wheat and barley varieties was sent by Ir Stubbs (IPO, Wageningen) to 25 sites in the UK and Eire.

Data on infection levels is available on request from NIAB.

# YELLOW RUST OF BARLEY

R H Priestley & P Byford

National Institute of Agricultural Botany, Cambridge

## 1) ISOLATES USED IN VIRULENCE TESTS

A total of 35 samples was received in 1976. These had been collected from Zoe (4 samples), Maris Mink (3), Ark Royal (2), Berac (2), Georgie (2), Sundance (2) and 23 other cultivars. Isolates were made from 18 samples, the remainder failed to sporulate on seedlings of Berac.

Seedling virulences have been identified in 17 of the 18 isolates. The remaining isolate was a mixture of virulence combinations.

## 2) VIRULENCE NUMBERING SYSTEM

Seedling virulences have been identified using the test cultivars given in Table 1. The role of adult plant resistances is being investigated. Common names for specific virulence combinations may be allocated when adult plant virulence information is available.

## 3) CHANGES IN VIRULENCE FREQUENCY

The frequency of critical virulences and virulence combinations in 1975 and 1976 is given in Table 2. Sampling was not carried out on a random basis and therefore the frequencies may not reflect those in the UK as a whole.

### 3.1 Astrix virulence (V 1), Sultan virulence (V 5) and V 1,5

The frequencies of V 1 and V 5 (and hence V 1,5) was 100 per cent in 1976. The frequency of V 1 and V 5 has been over 90 per cent since 1972 (see 1975 Annual Report) indicating that R 1 and R 5 are present in the majority of commercial barley cultivars.

Table 1. Sequentially numbered resistance factors

| Resistance factor | Test cultivar |
|---|---|
| R 1 | Astrix |
| R 2 | Bigo |
| R 3 | Varunda |
| R 4 | Mazurka |
| R 5 | Sultan |

---

3.2 Bigo virulence (V 2) and V 1,2,3,4,5

V 2 was identified in the UK population for the first time in 1975 in the combination V 1,2,3,4,5 (see 1975 Annual Report). It was not identified in 1976 probably due to the small number of isolates.

3.3 Varunda virulence (V 3) and V 1,3,5

V 3 was first identified in the UK population in 1972 and has most frequently been identified in the combination V 1,3,5. It was not identified in 1976 probably due to the small number of isolates.

3.4 Mazurka virulence (V 4) and V 1,4,5

V 4 was first identified in the UK population in 1974 and has most frequently been identified in the combination V 1,4,5. It was not identified in 1976 probably due to the small number of isolates.

4) EQUIVALENT PHYSIOLOGIC RACE NUMBERS

The following are equivalent:

| virulence combination | | Gassner & Straib race number |
|---|---|---|
| V 5 | = | 23 |
| V 1,5 | = | 24 |

Table 2. Frequency of critical virulences and virulence combinations

| | Common name | Frequency 1975 [1] | Frequency 1976 [2] |
|---|---|---|---|
| V 1 | Astrix virulence | 97 | 100 |
| V 2 | Bigo virulence | 3 | 0 |
| V 3 | Varunda virulence | 11 | 0 |
| V 4 | Mazurka virulence | 6 | 0 |
| V 5 | Sultan virulence | 98 | 100 |
| V 1,4,5 | - | 10 | 0 |
| V 1,4,5 | - | 6 | 0 |
| V 1,3,4,5 | - | 0 | 0 |
| V 1,2,3,4,5 | - | 3 | 0 |

notes

1) from seedling tests with 69 isolates

2) from seedling tests with 17 isolates

# BROWN RUST OF BARLEY

By B.C. Clifford and E. Jones

Welsh Plant Breeding Station, Aberystwyth.

Only 16 samples were received, 3 from Lofa Abed, 3 from breeding lines and one each from Armelle, Topper, Abacus, Georgie, Sundance, Varunda, Midas, Hassan, Welam and Astrix. Of the 12 isolates cultured successfully, 6 carried virulence to gene $Pa_3$ and 4 virulence to the CI 1243 resistance. These virulences were first detected in the 1975 survey. Neither resistance occurs in current varieties. One culture was identified which combines these virulences in one genotype and this was isolated from Varunda. A new standard set of international differentials was used together with a supplementary set of U.K. differentials. These are listed in the following table where the virulence spectra of the important races indentified in 1976 are given.

| Differential(Resistance factor) | Isolate | | |
|---|---|---|---|
| | BRS-76-12 | BRS-76-3 | BRS-76-2 |
| Sudan (Pa) | S | S | S |
| Peruvian ($Pa_2$) | S | S | S |
| Ribari ($Pa_3$) | S | R | S |
| Gold ($Pa_4$) | S | S | S |
| Quinn ($Pa_2$ $Pa_5$) | S | S | R |
| Bolivia ($Pa_2$ $Pa_6$) | S | S | S |
| Cebada Capa ($Pa_7$) | R | R | R |
| Egypt 4 ($Pa_8$) | S | S | S |
| Sultan | S | S | S |
| CI 1243 | S | S | R |
| Batna | S | S | S |
| Reka No. 1 | S | S | S |
| Ricardo | S | S | S |

The changes in the set of differentials follow from an agreement reached by barley brown rust workers at the 1976 Rust Conferences at Interlaken, Switzerland. Standard surveying and testing procedures were agreed and the use of the octal system of nomenclature was suggested to designate virulence combinations (races). The detailed proposal is to be published in the next issue of the Cereal Rusts Bulletin of the European and Mediterranian Cereal Rusts Foundation.

Some samples of brown rust were received from fields of the partially resistant varieties Lofa Abed and Armelle which showed higher than expected levels of infection. Quantitative tests on seedlings and adult plants failed to detect any specific virulence of the isolates to their host varieties. However, these isolates will be further tested in field isolation nurseries in 1977 and arrangements have been made with A.D.A.S., Starcross, Devon to sow trap nurseries of partially resistant tester varieties in field crops of Lofa Abed, Hassan and Armelle in Devon and Cornwall so that this potentially dangerous situation can be monitored more closely.

BROWN RUST OF WHEAT

Clifford, B. C., E. Jones

Welsh Plant Breeding Station, Aberystwyth

and R. H. Priestley

National Institute of Agricultural Botany, Cambridge

A total of 32 samples were received from Maris Ranger (6), Maris Kinsman (5), Maris Hobbit (4), Maris Sportsman (3), Maris Freeman (2), Maris Huntsman (2) and one each from Maris Fundin, Mega, Flinor, Cappelle Desprez, Drabant, Talent, Manella, Kranich and one from the spring wheat Sappo. One sample from winter rye was also received. Seven samples failed to culture. The remainder were tested on seedlings of the following varieties and breeding lines:- Maris Ranger, Maris Hobbit, Maris Kinsman, Sterna, Score, Sappo, Maris Halberd, Maris Dove, Kolibri, Anfield, Highbury, Aintree, 238/14/7/1/4, 238/35/8/4/10, 238/62/7/9/4, Aquila, Waggoner, Forester, Armada, Sportsman, Maris Freeman, Mega, Cappelle Desprez and Maris Huntsman.

The majority of varieties were susceptible as seedlings to the majority of cultures, only Forester, which probably derives its resistance from rye via Mildress, was resistant to all cultures. Clement, which also carries resistance from rye, was similarly resistant in previous tests. The culture from winter rye was fully or partially virulent on all varieties except Forester: this has epidemiological implications. Ten cultures were virulent on Sappo and Maris Halberd, spring varieties with apparently the same resistance. Hobbit, Anfield, 238/14/7/1/4 and 238/62/7/9/4 gave similar patterns of response and would appear to carry the same resistance. The most widely virulent culture was from Sportsman to which only Forester was resistant. These results enable the varieties to be placed in groups according to their patterns of resistance.

| | | |
|---|---|---|
| Group | 1 | Forester |
| " | 2 | Sappo, Maris Halberd |
| " | 3 | Sterna |
| " | 4 | Hobbit, Anfield, 238/14/7/1/4, 238/62/7/9/4 |

Comparative seedling and adult plant tests were carried out at the National Institute of Agricultural Botany, Cambridge. The tests consisted of 24 winter wheat cultivars inoculated with 4 isolates of Puccinia recondita. Seedling tests were carried out in controlled environment cabinets programmed for a 16h period at 18°C and an illumination of about 15,000 lx, and an 8h period at 11°C and no illumination. The adult plant tests were carried out in polythene tunnels similar to those used previously for P. striiformis. Reaction types were recorded in both seedling and adult plant tests; percent leaf area measurements were made on adult plants only.

The results are given in Table 1. Six specific resistances were identified of which two (R 1 and R 2) are overall resistances and four (R 3 - R 6) are adult plant resistances (sensu Zadoks). A number of cultivars in group 7 exhibited 'slow rusting' characterised by a susceptible reaction type at both seedling and adult plant growth stages with a relatively small percentage leaf area infection at the adult plant stage (eg Atou, Bouquet, Cappelle-Desprez, Flinor, Maris Freeman, Maris Widgeon and Mega).
Virulence for R 1 and R 3 was not detected although late in the season a few compatible pustules were noted on adult plants of Maris Ranger, Kinsman, Sportsman and Hobbit in the polythene tunnels. Isolates were made from these pustules for further examination. No compatible pustules were seen on the cultivar Clement.

In 1974 and 1975 scattered but severe natural infections were seen in NIAB trial plots and commercial fields of Maris Huntsman in southern England. The infection levels were considerably greater than expected from test plots inoculated with isolate 61/37 at NIAB.

In the polythene tunnel test, isolate 74/2 (ex severely infected field of Maris Huntsman) produced a greater percentage leaf area infected on Maris Huntsman than did isolate 61/37 indicating that change in the pathogen had occurred resulting in increased virulence for Maris Huntsman.

A mixture of the four isolates in equal proportions was also used in the adult plant polythene tunnel test. The results are given in Table 2. Susceptible responses were expressed by all cultivars except those in groups 1 and 2 of Table 1. A comparison of the data in Tables 1 and 2 shows that all the specific virulences present in the individual isolates were also expressed in the mixture. This has considerable implications for routine cultivar resistance evaluation programmes as the use of isolate mixtures instead of a series of individual isolates would considerably reduce the amount of work involved.

Table 1.

1976 BROWN RUST OF WHEAT POLYTHENE TUNNEL AND SEEDLING TEST DATA (NIAB)

Sowing date: 11 November 1975
Inoculation dates: 27 February, 7 April, 27 April, 11 May 1976
Assessment dates: 2 June, 9 June, 16 June, 24 June 1976

In table, values are mean Percent Attack from 3 rep tussocks (4 dates)

In table, reaction types R (resistant) var (variable) S (susceptible) from controlled environment seedling test / adult plant Polythene tunnel test

| Variety groups | | Isolate: 74/2 | 73/3 | 61/37 | 74/11 | |
|---|---|---|---|---|---|---|
| 1. | Clement | 0 R/R | 1 R/R | 0 R/R | 0 R/R | 'R 1' |
| 2. | Maris Ranger | 1 S/R | 0 S/R | 0 S/R | 1 S/R | 'R 3' |
| | Kinsman | 1 S/R | 0 S/R | 0 S/R | 0 S/R | |
| | Sportsman | 1 S/R | 0 S/R | 0 S/R | 1 S/R | |
| 3. | Hobbit | 1 var/R | 0 var/R | 0 S/R | 1 S/R | 'R 2 + 4' |
| 4. | Maris Fundin | 2 var/R | 1 var/R | 28 S/S | 40 S/S | 'R 2' |
| 5. | Maris Huntsman | 27 S/S | 17 S/S | 9 S/S | 10 S/R | 'R 5' |
| | Maris Nimrod | 32 S/S | 20 S/S | 5 S/S | 9 S/R | |
| 6. | Gamin | 0 S/R | 0 S/R | 0 S/R | 3 S/S | 'R 6' |
| 7. | Atou | 4 S/S | 3 S/S | 5 S/S | 5 S/S | |
| | Bouquet | 2 S/S | 1 S/S | 5 S/S | 3 S/S | |
| | Cappelle-Desprez | 2 S/S | 0 S/S | 1 S/S | 3 S/S | |
| | Champlein | 7 S/S | 4 S/S | 6 S/S | 7 S/S | |
| | Flanders | 15 S/S | 6 S/S | 6 S/S | 13 S/S | |
| | Flinor | 4 S/S | 2 S/S | 0 S/S | 5 S/S | |
| | Grenade | 17 S/S | 5 S/S | 13 S/S | 12 S/S | |
| | Hawk | 10 S/S | 4 S/S | 13 S/S | 17 S/S | |
| | Kador | 12 S/S | 5 S/S | 1 S/S | 6 S/S | |
| | Maris Freeman | 6 S/S | 3 S/S | 5 S/S | 9 S/S | |
| | Maris Widgeon | 3 S/S | 3 S/S | 3 S/S | 11 S/S | |
| | Mega | 7 S/S | 1 S/S | 2 S/S | 5 S/S | |
| | Score | 35 S/S | 10 S/S | 23 S/S | 42 S/S | |
| | Val | 6 S/S | 2 S/S | 6 S/S | 13 S/S | |
| | West Desprez | 9 S/S | 5 S/S | 2 S/S | 13 S/S | |
| | | 'V 5' | 'V 5' | 'V 2 + 5' | 'V 2 + 6' | |

Boxed (solid line) = overall resistance: Clement (all isolates); Hobbit and Maris Fundin (74/2, 73/3).

Boxed (dashed line) = adult plant resistance: Maris Ranger, Kinsman, Sportsman (all isolates); Hobbit (61/37, 74/11); Maris Huntsman, Maris Nimrod (74/11); Gamin (74/2, 73/3, 61/37).

Table 2. Mean percent leaf area infected values from 3 replicate tussocks of 24 cultivars inoculated with a mixture of isolates

For sowing dates, inoculation dates and assessment dates see Table 1.

| | | | |
|---|---|---|---|
| Clement | 0 | Atou | 8 |
| | | Bouquet | 8 |
| Maris Ranger | 1 | Cappelle-Desprez | 3 |
| Kinsman | 1 | Champlein | 5 |
| Sportsman | 0 | Flanders | 15 |
| | | Flinor | 4 |
| Hobbit | 1 | Grenade | 16 |
| | | Hawk | 17 |
| Maris Fundin | 26 | Kador | 6 |
| | | Maris Freeman | 10 |
| Maris Huntsman | 24 | Maris Widgeon | 8 |
| Maris Nimrod | 23 | Mega | 3 |
| | | Score | 24 |
| Gamin | 3 | Val | 11 |
| | | West Desprez | 11 |

The seedling resistance of Maris Fundin was variable in expression in these tests confirming previous anomalous results with this variety. The possibility of the resistance being temperature sensitive was investigated by testing seedlings under 3 controlled environments of (1) 15$^{o}$C for a 16h photoperiod and 10$^{o}$C for an 8h dark period, (2) 25$^{o}$C, 16h/20$^{o}$C, 8h and (3) a constant temperature of 20$^{o}$C for a 16h photoperiod, 8h dark period. Resistance was expressed fully at 25/20$^{o}$C and 20$^{o}$C constant temperature but the plants were fully susceptible at 15/10$^{o}$C.

The existence of temperature sensitive and adult plant resistances in the wheat brown rust system complicate the testing procedures necessary to assess pathogen variability. Temperature relationships in polythene tunnels may modify the interaction and consequently comparative tests of polythene tunnel nurseries at the W.P.B.S. are being carried out in 1977 using isolates from the 1976 and previous surveys.

# MILDEW OF BARLEY

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

A total of 280 samples was received, including 28 from winter barleys. Table 1 shows the number of samples obtained from each of the host resistance groups and also shows the appropriate R group to which a number of new, previously untested, varieties belong.

Table 1. Source of barley mildew isolates received in 1976

| Resistance group | and gene | No. samples | Source varieties |
|---|---|---|---|
| Ro | - | 17 | Maris Otter, Golden Promise, Proctor |
| R1 | 'Mlh' | 11 | Igri, Sonja |
| R2 | Mlg + 'x' | 14 | Imber, Julia, Katy, Zephyr |
| R3 | Mla6 | 2 | Midas |
| R4 | 'Mlv' (2 genes) | 10 | Lofa Abed, Mala Abed |
| R5 | 'Mlas' = (Mla12) | 11 | Baltsar, Hassan, Maris Trojan |
| R6 | 'Mla4/7' (2 genes) | 33 | Ark Royal, Nordal, RPB 261/70 |
| R7 | Mla9 (2 genes) | 23 | Tyra, W6345 |
| R8 | 'Mlar' (Rupee) | 1 | Vanja ? |
| R1+2 | | 10 | Astrix, Athene |
| R2+4 | | 51 | Abacus, Georgie, Luke, Sundance |
| R2+5 | | 86 | Aramir, Athos, Porthos, Pirouette, Uta, VDH 427/72 Zoe |
| R2+5+? | | 21 | Maris Mink |
| R2+4+5 | | 7 | Menuet |
| R2+6 | | 2 | Mazurka |
| R2+7? | | 1 | Akka |
| Unknown | | 2 | variety unknown |

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

Table 2. Mean relative numbers of colonies produced from bulk isolates from barley varieties arranged in appropriate R groups. Isolates non-virulent on test seedlings of the varieties from which they were collected have been omitted

| Source | Relative nos. of colonies on test seedlings* | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | R1 | R2 | R3 | R4 | R5 | R6 | R7 | R2+ 5+? | R2+6 | R2+7 | No. of Isolates |
| R0 G. Promise | 66 | 29 | 24 | <1 | 30 | 4 | 0 | 12 | 7 | 1 | 8 |
| M. Otter | 89 | 15 | 92 | 0 | <1 | <1 | 0 | 0 | 0 | 0 | 1 |
| Proctor | 74 | 52 | 12 | 2 | 19 | 14 | 0 | 7 | 17 | 0 | 1 |
| R1 Igri | 91 | 46 | 27 | 0 | 11 | 39 | 0 | 13 | 67 | 0 | 3 |
| Sonja | 75 | 45 | 18 | 1 | 10 | 24 | 0 | 0 | 38 | 34 | 3 |
| R2 Imber | 55 | 56 | 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Julia | 48 | 41 | 21 | 2 | 33 | 38 | 0 | 25 | 21 | 1 | 2 |
| Katy | 87 | 57 | 2 | 0 | 2 | 26 | 0 | 0 | 96 | 0 | 1 |
| Zephyr | 104 | 62 | 57 | 11 | 33 | 11 | 0 | 44 | 11 | 0 | 2 |
| R3 Midas | 46 | 21 | 40 | 5 | 31 | 7 | 0 | 5 | 3 | 0 | 2 |
| R4 Mala A. | 39 | 13 | 35 | 60 | 2 | 2 | 0 | 0 | 4 | 0 | 2 |
| R5 Baltsar | 54 | 35 | 0 | 0 | 49 | 0 | 0 | 19 | 0 | 0 | 1 |
| Hassan | 48 | 44 | 40 | 1 | 80 | 0 | 0 | 84 | 0 | 0 | 1 |
| M. Trojan | 75 | 27 | 10 | 1 | 60 | 2 | 0 | 16 | 0 | 0 | 1 |
| R6 Ark Royal | 79 | 47 | 5 | 3 | 2 | 62 | 0 | 3 | 85 | 12 | 11 |
| Nordal | 63 | 23 | 0 | 0 | 0 | 68 | 0 | 0 | 60 | 3 | 1 |
| RPB 261/70 | 62 | 37 | <1 | 2 | 0 | 78 | 0 | 0 | 79 | 0 | 5 |
| R7 Tyra | 56 | 48 | 38 | 8 | 12 | 6 | 72 | 5 | 2 | 0 | 5 |
| R1+2 Astrix | 48 | 53 | 0 | 0 | 0 | 67 | 0 | 0 | 116 | 0 | 2 |
| Athene | 55 | 48 | 15 | 3 | 1 | 53 | 0 | 5 | 48 | 0 | 3 |
| R2+4 Abacus | 20 | 51 | 0 | 61 | 31 | 4 | 0 | 34 | 1 | 0 | 2 |
| Georgie | 53 | 67 | 0 | 91 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Luke | 49 | 52 | 54 | 67 | 5 | 0 | 0 | 0 | 0 | 0 | 1 |
| Sundance | 79 | 55 | 0 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| R2+5 Aramir | 79 | 46 | 12 | 1 | 51 | 11 | 0 | 49 | 17 | 0 | 6 |
| Athos | 55 | 38 | 24 | 2 | 51 | <1 | 0 | 32 | <1 | 0 | 9 |
| Porthos | 53 | 53 | 20 | 1 | 54 | 5 | 0 | 52 | 14 | 0 | 8 |
| Uta | 34 | 38 | 4 | 5 | 47 | 7 | 0 | 47 | 4 | 0 | 4 |
| VDH 427/72 | 61 | 14 | 0 | <1 | 47 | 0 | 0 | 4 | 0 | 0 | 1 |
| Zoe | 37 | 47 | 0 | 32 | 46 | 3 | 0 | 53 | 1 | 0 | 2 |
| R2+5+? M. Mink | 50 | 46 | 10 | 8 | 50 | 6 | 0 | 50 | 11 | 0 | 10 |
| R2+6 Mazurka | 85 | 140 | 0 | 2 | 5 | 80 | 0 | 2 | 48 | 27 | 1 |
| R2+7 Akka | 82 | 53 | 0 | 0 | 0 | 61 | 0 | 0 | 77 | 100 | 1 |

Value in Table = Virulence frequency x Virulence level *test seedlings:-

| | | | |
|---|---|---|---|
| R1 | Weih. 37/136, 41/145 | R6 | Tern, Wing |
| R2 | CP127422, Zephyr, Julia, Union | R7 | Tyra |
| R3 | Maris Concord, Midas | R2+5+? | M. Mink |
| R4 | Lofa Abed, Vada | R2+6 | Mazurka |
| R5 | Hassan, Sultan | R2+7 | Akka |

R0: Isolates from R0 varieties included eight from ethirimol-treated plots of Golden Promise in Scotland. These were notable for a relatively low frequency of virulence for R6 and high frequency for R5. Lack of virulence for R6 is explained by the small area of R6 varieties in Scotland. R5 varieties are also infrequent in that area: high frequency of the corresponding virulence may reflect the more widespread use of ethirimol in Scotland than in England since it was previously observed that there often appears to be an association between R5 virulence and insensitivity for ethirimol.

R1: Among isolates from this group virulence for R6, R2+6 and R2+7 was unexpectedly high, but may simply reflect interference from nearby plots of the corresponding varieties.

R2: Isolates from R2 varieties gave higher than average scores for most virulences. This presumably reflects selection for flexibility in the pathogen population, i.e. because R2 varieties have been common for a number of years, there is strong selection amongst pathogen populations on all varieties for those isolates with virulence for R2. On all varieties with resistance combinations, virulence for R2 is, of course, essential, since all current varieties with combined resistance possess R2. For these reasons, R2 varieties currently have little value for diversification purposes since relatively large numbers of spores from R2 crops will be able to infect most other varieties, and vice versa. The same is also largely true for R0 and R1 varieties.

The seedlings used to test for R2 virulence were of four varieties, including Zephyr and Julia. Isolates from Zephyr tended to produce more colonies on Zephyr than on Julia seedlings, and vice versa, reflecting the previously observed quantitative specialisation of the pathogen for these two varieties within the R2 group.

R3: The two varieties Maris Concord and Midas were used to test for R3 virulence. Isolates from Midas tended to produce similar numbers of colonies on both test varieties, but samples from other varieties generally produced more than twice as many colonies on M. Concord than on Midas seedlings. This confirmed the occurrence of a second, unknown, resistance factor in Midas virulence for which is less common than virulence for Mla6, the resistance gene in M. Concord.

R4: The varieties Vada and Lofa Abed were used to test for R4 virulence. Seedlings of both varieties were similarly affected by isolates with high levels of R4 virulence, but other isolates tended to produce more colonies on Vada than on Lofa Abed at low infection levels.

R5: Virulence for R5 was differentiated by the two test varieties, Sultan and Hassan, which revealed three levels of intra-group differentiation. Isolates from most R5 or R2+5 varieties generally produced more colonies on Sultan than on Hassan, but the reverse is true for isolates from Hassan. Isolates from other varieties also tended to produce more colonies on Sultan than on Hassan, but the difference was greater than with isolates from R5 and R2+5 varieties.

R6: Virulence for both R2 and R6 varieties was common in isolates from R6 varieties, so that they were able to produce a high level of infection on Mazurka, which has the combination, R2+6. There was little difference between the performance of the two seedling test varieties, Tern and Wing, except for a slight tendency for more colonies to be produced on Wing than on Tern.

R7: Tests with isolates from Tyra, and from R2+7, R6 and other groups have revealed a complex relationship between the resistances of these varieties which is summarised below:

| | | Probable host genes | | | | |
|---|---|---|---|---|---|---|
| Resistance Group | Variety | Mlg (R2) | Mla4/7 (R6) | Hl063 (R6) | Mla9 (R7) | Ml? (R7) |
| R6 | Tern, Wing | - | + | + | - | - |
| R2+6 | Mazurka | + | + | + | - | - |
| R7 | Tyra | - | - | - | + | + |
| R2+7 | Akka | + | - | + | + | - |

The results obtained suggest that there are at least four genes in the two varieties with resistance derived from Monte Cristo (R7), but that only one gene is common to both Akka and Tyra. This explains why some isolates from each of the varieties do not attack both varieties. A single recent result with a 1975 isolate from Vada showed that it was virulent on Tyra but not Akka: this virulence had not been detected prior to 1976, since Akka was the only representative of the R7 group used for testing before 1976.

R1+2: Isolates from Astrix and Athene had a high level of virulence for R6 and R2+6 varieties, probably from the effects of plot interference.

R2+4: The majority of isolates from this group (15 out of 20) were non-virulent on R4 test seedlings, which suggests that the highest level of virulence for this group has not yet become common.

R2+5: Virulence for Maris Mink (R2+5+?) appears to be relatively common among isolates from R2+5 varieties probably because M. Mink has acted as a major source of isolates with combined virulence for R2+5.

The performance of isolates from R2+5 varieties at seven sites was compared on test seedlings of Zephyr and Julia with isolates from Ark Royal (R6) at the same sites. The R2+5 varieties selected isolates relatively less virulent on Zephyr than those selected by Ark Royal, but relatively more virulent on Julia than those selected by Ark Royal.

R2+5+?: A circular was issued previously concerning the detection of pathogen isolates with specific virulence for Maris Mink. Of the 16 isolates tested from this source, only 10 revealed the combination of three factors necessary for a high level of virulence on the variety. It is not yet known whether this virulence combination is increasing in frequency in the general population, and, if so, how fast.

R2+6: Availability of an isolate virulent on R6 only, confirmed that Mazurka, which was resistant to it, possesses the combination R2+6.

R2+7: See R7.

The differences recorded in relation to the responses of the test varieties within each R group confirmed the close relationship between the results obtained from quantitative tests with seedling leaf tissue and those observed in the field. However, the data given in Table 2 comprise two kinds of value. If we assume that all individuals within a bulk isolate have a high level of virulence for the variety from which the isolate was taken, i.e. the virulence frequency is 100%, then the test value on seedlings of the same variety indicates the virulence level of those individuals. For example, in Table 2, isolates from R1 varieties give a mean colony number of $\frac{91+75}{2}$ = 83 on test seedlings of R1 : this is the virulence level. The values for each individual R group, calculated in this way, are as follows:

| | R1 | R2 | R3 | R4 | R5 | R6 | R7 |
|---|---|---|---|---|---|---|---|
| Virulence level | 83 | 53 | 40 | 60 | 63 | 67 | 72 |

The second value relates to non-corresponding virulences, which is a function of virulence level and virulence frequency. For example, isolates from R1 varieties in Table 2 give a mean value of $\frac{46+45}{2}$ = 46 on test seedlings of R2 varieties. If we assume that R2 virulent individuals within the isolate have a virulence level of 53 for R2 seedlings (see above), then the frequency of this virulence level = $\frac{46}{53}$ = 87%, or,

Table 2 value = virulence level x virulence frequency

i.e. 46 = 53 x 87%

(or, 53 = 53 x 100% for virulence on 'own' variety).

The values for non-corresponding virulences, where frequency is assumed to be less than 100%, are given in Table 3.

Table 3. Mean colony numbers produced on test seedlings with resistance different from the varieties from which the isolates were obtained

a. Individual R groups

| Isolate | test seedlings R1 | R2 | R3 | R4 | R5 | R6 | R7 | R2+5+? | R2+6 | R2+7 |
|---|---|---|---|---|---|---|---|---|---|---|
| R0 | 69 | 30 | 29 | <1 | 26 | 4 | 0 | 10 | 7 | 1 |
| R1 | - | 46 | 22 | <1 | 11 | 32 | 0 | 7 | 50 | 17 |
| R2 | 74 | - | 28 | 4 | 22 | 21 | 0 | 23 | 27 | <1 |
| R3 | 46 | 21 | - | 5 | 31 | 7 | 0 | 5 | 3 | 0 |
| R4 | 39 | 13 | 35 | - | 2 | 2 | 0 | 0 | 4 | 0 |
| R5 | 59 | 35 | 17 | 1 | - | 1 | 0 | 40 | 0 | 0 |
| R6 | 73 | 43 | 4 | 3 | 1 | - | 0 | 2 | 78 | 8 |
| R7 | 56 | 48 | 38 | 8 | 12 | 6 | - | 5 | 2 | 0 |
| Mean | 59 | 34 | 25 | 3 | 15 | 10 | 0 | 12 | 21 | 3 |

b. R group combinations

| Isolate | test seedlings R1 | R2 | R3 | R4 | R5 | R6 | R7 | R2+5+? | R2+6 | R2+7 |
|---|---|---|---|---|---|---|---|---|---|---|
| R1+2 | - | - | 9 | 2 | 1 | 59 | 0 | 3 | 73 | 0 |
| R2+4 | 44 | - | 11 | - | 13 | 2 | 0 | 13 | <1 | 0 |
| R2+5 | 55 | - | 16 | 4 | - | 5 | 0 | 43 | 8 | 0 |
| R2+5+? | 50 | | 10 | 8 | - | 6 | 0 | - | 11 | 0 |
| R2+6 | 85 | - | 0 | 2 | 5 | - | 0 | 2 | - | 27 |
| R2+7 | 82 | - | 0 | 0 | 0 | 61 | - | 0 | 77 | - |
| Mean | 63 | - | 8 | 3 | 5 | 27 | 0 | 12 | 34 | 5 |

From Tables 3a and 3b it can be seen that virulence for test seedlings of R groups 1 and 2, is common in isolates from all varieties. Also reading across Table 3a, it can be seen that isolates from varieties in R groups 0, 1 and 2 produce relatively high colony numbers on the majority of test seedlings.

The values in the two boxes represent the best R group combinations in the diversification scheme. They show that isolates from each of groups R3, R4, R5 and R6 have only a limited ability to infect test seedlings of the other three groups. Data from the Tables and elsewhere indicate that there has been little change from 1975, although it is possible that virulence for the combination R3/R5 may increase relatively quickly.

Virulence for R7 is still uncommon generally, which means that R7 would be a useful addition to the diversification scheme. However, isolates with R7 virulence have relatively high levels of virulence for other varieties which will probably limit the long-term usefulness of this group.

Table 4 examines the performance of isolates from varieties with combined resistance against test seedlings of varieties carrying the resistance components separately. It is argued that the highest level of virulence which can be attained amongst these isolates will be the same as the highest values for isolates obtained from varieties which carry the corresponding resistances separately, so that the latter values can be used as 'expected' values in the Table.

Table 4. Expected and observed colony numbers produced by isolates from R group combinations on test seedlings of varieties which carry the corresponding R factors separately. Note, R2 is common to all combinations

| Test seedling | Isolates obtained from R1+2 | R2+4 | R2+5 | R2+5+? | R2+6 | R2+7 |
|---|---|---|---|---|---|---|
| R2 exp. | 53 | 53 | 53 | 53 | 53 | 53 |
| obs. | 50 | 55 | 44 | 46 | 140 | 53 |
| Second factor | | | | | | |
| exp. | 83 | 60 | 63 | 63 | 67 | - |
| obs. | 52 | 64 | 50 | 50 | 80 | - |
| No. isolates | 5 | 20 | 30 | 16 | 1 | 1 |
| No. virulent | 5 | 5 | 30 | 10 | 1 | 1 |

Isolates from R2+5 and R2+5+? varieties appear to be less well able to infect seedlings of R2 and R5 test varieties than do isolates obtained from R2 and R5 varieties. This is consistent with earlier observations of the relatively low fitness of pathogen isolates with combined virulence for R2 and R5.

Isolates with combined virulence for R2 and R4 seem to be as equally infective as isolates with separate virulences, but it should be noted that only five out of 20 isolates from R2+4 varieties show this characteristic, indicating that the R2+4 virulence combination is not fully adapted.

The apparently anomalous values for R2+6 were obtained with a single isolate.

MILDEW OF WHEAT

Fiona G.A. Bennett
Plant Breeding Institute, Cambridge

A total of 222 samples was received from 25 winter and 5 spring wheat varieties (Table 1). All samples received were treated as in 1975 and inoculated as bulk isolates to a set of differential varieties.

Table 1. Source of wheat mildew isolates received in 1976

| Resistance Group | Gene | Chromosome Location | No.of Samples | Source varieties |
|---|---|---|---|---|
| R0 | - | - | 33 | Champlein, Hobbit, Joss Cambier, Flinor, Gamin, Hawk, Kador, Score, M. Widgeon, Bouquet, Atou, Chalk, Freeman, Cappelle |
| R1 | Pm1 | 7A | 1 | Anfield |
| R2 | Pm2 | 5D | 3 | Sportsman |
| R7 | Mlr | Rye 1R | 2 | Clement, Aurora |
| R9 | (Ibis)* | ? | 7 | Flanders, Mega |
| R2+4 | Pm2+Mle | 5D+2A | 6 | Sappo, RPB6/73 |
| R2+6 | Pm2+Pm6 | 5D+2B | 25 | M. Fundin, Kinsman, M. Templar, M. Huntsman |
| R2+8 | Pm2+(T.durum) | 5D+4B | 3 | M. Dove, Cebeco 180 |
| R5+? | pm5+? | 7B | 1 | Sicco |
| R2+6+4 | Pm2+Pm6+Mle | 5D+2B+2A | 2 | Walter, Timmo |
| Unknown | - | - | 19 | RPB475/71A, RPB662/71A, RPB664/71A, RPB25/72, FD6410/B70, FD6412/209 |

*Brackets indicate gene not located or officially named yet.

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

Table 2. Relative numbers of colonies produced from bulk isolates from wheat varieties arranged in appropriate R groups. Isolates non-virulent on test seedlings of the varieties from which they were collected have been omitted

a. Winter varieties

| Source | | Relative numbers of colonies on test seedlings* | | | | | | | | | | | | | Number of |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R1 | R2 | R3a | R3b | R3c | R4 | R5 | R7 | R9 | R2+4 | R2+6 | R2+6+? | R2+8 | Isolates |
| R0 | Flinor | 49 | 96 | 48 | 5 | 50 | 4 | 41 | 29 | 72 | 12 | 8 | 3 | 17 | 5 |
| | Gamin | 68 | 84 | 30 | 1 | 35 | 1 | 28 | 8 | 42 | <1 | 4 | 0 | 33 | 4 |
| | Hawk | 90 | 99 | 98 | 0 | 1 | 0 | 40 | 34 | 82 | 0 | 0 | 0 | 0 | 1 |
| | Kador | 28 | 63 | 55 | 0 | 55 | 3 | 8 | 5 | 49 | 0 | 0 | 3 | 5 | 1 |
| | Score | 60 | 90 | 29 | 0 | 58 | 6 | 17 | 14 | 24 | 1 | 5 | 3 | 45 | 4 |
| | M. Widgeon | 40 | 53 | 37 | 0 | 62 | 2 | 16 | 1 | 41 | 19 | 13 | 1 | 26 | 2 |
| | Bouquet | 76 | 94 | 11 | 1 | 4 | 8 | 15 | 0 | 18 | 0 | 20 | 1 | 59 | 2 |
| | Atou | 60 | 67 | 7 | 0 | 65 | 4 | 3 | 0 | 15 | 0 | 0 | 0 | 0 | 2 |
| | Chalk | 4 | 23 | 80 | 0 | 14 | 17 | 60 | 0 | 67 | 0 | 1 | 0 | 0 | 1 |
| | M. Freeman | 37 | 63 | 24 | 0 | 34 | 7 | 10 | 0 | 37 | 0 | 12 | 0 | 43 | 3 |
| | Cappelle | 5 | 51 | 17 | 4 | 73 | 5 | 2 | - | 26 | 0 | 11 | 3 | 52 | 2 |
| | Champlein | 32 | 38 | 21 | 6 | 20 | 4 | 21 | 0 | 41 | 0 | 6 | 0 | 0 | 3 |
| | Joss Cambier | 17 | 50 | 42 | 3 | 33 | 10 | 33 | 2 | 41 | 0 | 5 | 0 | 2 | 2 |
| | Hobbit | 33 | 40 | 50 | 29 | 39 | 15 | - | 0 | 24 | 0 | 0 | 0 | 0 | 1 |
| R2 | Sportsman | 63 | 88 | 0 | 0 | 5 | 43 | 0 | 0 | 23 | 19 | 0 | 0 | 76 | 3 |
| R7 | Clement | <1 | 0 | 0 | 0 | 0 | 1 | 0 | 116 | 30 | 0 | 0 | 0 | 0 | 1 |
| R9 | Flanders | 24 | 59 | 94 | 0 | 11 | 0 | 32 | 7 | 87 | 0 | 3 | 1 | 17 | 4 |
| | Mega | 105 | 75 | 74 | 4 | 37 | 36 | 63 | 0 | 47 | 34 | 31 | 25 | 38 | 3 |
| R2+6 | Fundin | 2 | 80 | 24 | 7 | 19 | 11 | 31 | 1 | 33 | 0 | 52 | 39 | 34 | 6 |
| | Kinsman | 65 | 25 | 3 | 0 | 31 | 6 | 7 | 0 | 36 | 0 | 22 | 23 | 0 | 2 |
| | Templar | 0 | 73 | 8 | 0 | 52 | 7 | 6 | 37 | 10 | 0 | 27 | 48 | 6 | 1 |
| | Huntsman | 36 | 105 | 15 | 2 | 25 | 8 | 19 | 1 | 40 | 0 | 88 | 76 | 7 | 12 |
| R2+8 | Cebeco 180 | 54 | 132 | 44 | 1 | 17 | 18 | 26 | 4 | 68 | 51 | 3 | 0 | 110 | 2 |

b. Spring varieties

| Source | | Relative numbers of colonies on test seedlings* | | | | | | | | | | | | | Number of |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | R1 | R2 | R3a | R3b | R3c | R4 | R5 | R7 | R9 | R2+4 | R2+6 | R2+6+? | R2+8 | Isolates |
| R1 | Anfield | 80 | 14 | 36 | 0 | 12 | 0 | 48 | 0 | 36 | 2 | 0 | 0 | 14 | 1 |
| R2+8 | M. Dove | 0 | 140 | 121 | 0 | 12 | 0 | 29 | 0 | 78 | 0 | 0 | 0 | 124 | 1 |
| R2+4 | Sappo | 81 | 120 | 18 | 0 | 32 | 147 | 16 | 43 | 48 | 125 | 0 | 0 | 85 | 3 |
| | RPB 6/73 | 94 | 79 | 68 | 0 | 6 | 78 | 42 | 0 | 52 | 86 | 5 | 1 | 83 | 3 |
| R4+5 ? | Sicco | 110 | 16 | 110 | 0 | 47 | 10 | 97 | 0 | 108 | 10 | 7 | 0 | 11 | 1 |
| R2+6+4 | Walter | 129 | 153 | 35 | 0 | 80 | 58 | 0 | 0 | 15 | 247 | 75 | 58 | 65 | 1 |
| | Timmo† | 1 | 112 | 0 | 0 | 0 | 52 | 0 | 0 | 31 | 0 | 88 | 69 | 12 | 1 |

*test seedlings:-

| | | | |
|---|---|---|---|
| R1 | Axminster | R7 | St.14/44 |
| R2 | Ulka, Nimrod | R9 | Flanders, Mega |
| R3a | Asosan | R2+4 | Sappo |
| R3b | Chul | R2+6 | Maris Fundin |
| R3c | Sonora | R2+6+? | Maris Huntsman |
| R4 | Weih M1, Khapli | R2+8 | H13471 |
| R5 | Hope | | |

† The Timmo isolate appears to differ considerably from the Walter isolate: with only one isolate from each variety it is difficult to say if these differences are real or due to, say, plot interference.

1. The Ro group includes varieties which provide no evidence in their pedigrees for possession of major resistance genes and which become infected in the field but from which isolates do not demonstrate a particularly high frequency of any known virulence type. Varieties within this group may differ with respect to their mildew resistance genes as is evident from the strikingly different patterns of virulence produced by pathogen populations from them. For example, isolates from Atou and Chalk appear to behave in a reciprocal fashion with respect to most of the virulences for which they have been tested. It may transpire that some varieties in this group e.g. Kador, Maris Widgeon and Joss Cambier, possess resistance genes which are presently unknown.

2. Virulence for R2 has continued to increase on non-R2 varieties. This has been paralleled by a steady increase in the frequency of virulence for Fundin (R2+6) on the same varieties. Conversely, virulence for Huntsman alone (R2+6+?) has remained undetectable in the population. Where specific selection for it has existed in the form of varieties derived from _T. timopheevi_ (see 1975 report, p.28) it has always occurred in the presence of the Fundin virulence. These relationships are set out below:

Number of survey isolates with either Huntsman or Fundin virulence, both, or neither

| | Total | Huntsman | Fundin | Both | Neither |
|---|---|---|---|---|---|
| From CI12633-derived varieties | 27 | 0 | 0 | 23 | 4 |
| From other varieties | 50 | 0* | 19 | 9 | 21 |

*Very slight infection from one isolate

Further inspection of Table 2a reveals that the frequency of infection, where it occurs, is most often lower on Maris Huntsman than on Maris Fundin. This evidence supports previous observations that Maris Huntsman is currently the most resistant variety in the CI 12633 group, probably due to the presence of an additional gene or genes for resistance. This restriction of the pathogen population is probably instrumental in maintaining Maris Huntsman's resistance in spite of it being grown on a large part of the national acreage (over 30% in 1974-76).

3. Virulence for the rye mildew resistance (R7) has become more widely distributed this year even though the overall mean frequency has only risen from 4% to 11%. The spread of this virulence is particularly

noteworthy since no variety with the corresponding resistance has yet been grown on any scale in Britain. One isolate from Clement confirmed that this variety does possess the rye resistance so that an increase in popularity of this variety would be expected to increase further the frequency of this virulence. The rye mildew resistance is common in varieties grown on the continent of Europe which may be responsible for the small increase observed in the corresponding virulence frequency in this country.

4. Seedling segments of varieties in the R9 group were susceptible to the majority of survey isolates. Isolates taken from Flanders and Mega did not exhibit any characteristics which might distinguish them from the R0 group of varieties.Their resistance in the field, however, and the few isolates which were non-virulent on them (notably one from St. John's Island, Jersey) suggest that there may be at least two resistance genes operating in these varieties: one which acts throughout the life of the plant and for which virulence is widespread in the population, and one which acts only in the adult plant and for which virulence is as yet rare. It should be noted that Flanders and Mega have been grouped together because of general similarities: there may be minor gene differences which are undetectable by these tests. Evidence for this comes from the observation that samples from Mega tended to produce more colonies on Mega test seedlings whilst samples from Flanders produced more colonies on Flanders test seedlings.

5. Two isolates from the winter variety Cebeco 180 indicate that this variety belongs to the R2+8 group, to which Maris Dove also belongs. This is the first known instance of a winter variety having exactly the same major resistance factors as a spring variety, although R2 has been common to both types for some time.

6. Three isolates from the spring variety RPB 6/73 indicate that this variety belongs to the R2+4 group to which Sappo also belongs. This resistance combination has been rapidly overcome by the pathogen.

7. The inheritance of resistance in Sicco remains uncertain. One isolate from it suggests that R5 may be one of the components.

8. The R2+6+4 group is the most complex. It is noteworthy that the *T. timopheevi* resistance (R2+6) is now likely to become common on the

spring acreage (through Timmo) as well as on the winter acreage (through Maris Huntsman). It remains to be seen whether this resistance will be able to withstand the concomitant increase in selection pressure on the pathogen population to overcome it. More samples are required from Walter and Timmo before the apparent similarities observed this year can be confirmed.

As in the barley mildew report, the data in Table 2 are made up of two components: the frequency of a particular virulence in the population and the infectivity or level of that virulence on the various test seedlings. Assuming that the frequency of a particular virulence is 100% in samples taken from the corresponding host, then the test result on seedlings with the same resistance gives us a value for its virulence level. These values, calculated as means from all varieties in one host R group are given below:

| | R1 | R2 | R7 | R9 | R2+4 | R2+6 | R2+6+? | R2+8 |
|---|---|---|---|---|---|---|---|---|
| Virulence level | 80 | 88 | 116 | 70 | 106 | 76 | 65 | 115 |

It is significant that the resistance with the lowest corresponding virulence level is the Huntsman resistance.

Table 3 gives the values for non-corresponding virulences where frequencies are assumed to be less than 100% as described above.

Table 3. Mean colony numbers produced on test seedlings, with resistance different from the varieties from which the isolates were obtained

| | Test seedlings | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Isolate | R1 | R2 | R3a | R3b | R3c | R4 | R5 | R7 | R9 | R2+4 | R2+6 | R2+6+? | R2+8 |
| R0 | 46 | 71 | 34 | 3 | 41 | 5 | 23 | 9 | 41 | 3 | 7 | 1 | 25 |
| R1 | - | 14 | 36 | 0 | 12 | 0 | 48 | 0 | 36 | 2 | 0 | 0 | 14 |
| R2 | 63 | - | 0 | 0 | 5 | 43 | 0 | 0 | 23 | 19 | 0 | 0 | 76 |
| R7 | <1 | 0 | 0 | 0 | 0 | 1 | 0 | - | 30 | 0 | 0 | 0 | 0 |
| R9 | 59 | 66 | 85 | 2 | 22 | 15 | 45 | 4 | - | 15 | 15 | 11 | 26 |
| R2+4 | 88 | - | 43 | 0 | 19 | - | 29 | 22 | 50 | - | 3 | 1 | 84 |
| R2+6 | 30 | - | 18 | 3 | 28 | 10 | 23 | 3 | 40 | 0 | - | - | 15 |
| R2+8 | 36 | - | 70 | <1 | 15 | 12 | 27 | 3 | 71 | 34 | 2 | 0 | - |

It can be seen from Table 3 (omitting the isolate from group R7) that virulence for test seedlings in R groups 1, 2, 9 and 2+8 is common in isolates from all varieties. Furthermore, reading across Table 3, it can be seen that isolates from varieties in R groups 0, 9, 2+4 and 2+8 give generally high values on the majority of test seedlings, which would suggest that varieties in these groups would not be good candidates to grow together in order to reduce the risk of mildew spread. However it is as yet too early to produce definite recommendations for a diversification scheme. The R7 isolate had no virulence for test seedlings possessing R2 which could further indicate a continental origin for this population.

Table 4 sets out data obtained from mobile nurseries in such a way that expected and observed frequencies of infection on seedlings with combined resistances may be compared.

Table 4. Mean colony numbers on test seedlings exposed in mildew infected fields, expressed as a percentage of those occurring on the susceptible control

| | Host Fields | | | | |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| Test seedling | Huntsman (R2+6) | Sportsman (R2) | PBI Pedigree Plots | Fundin (R2+6) | Champlein (R0) |
| R2 (Nimrod) | 59 | 86 | 65 | 48 | 26 |
| R4 (ELS) | 40 | 5 | 14 | 2 | 7 |
| R2+4 exp. | 24 | 4 | 9 | 1 | 2 |
| obs. | 0 | 0 | 0 | 0 | 5 |
| R5 (Hope) | 22 | 5 | 33 | 0 | 9 |
| R4+5 exp. | 9 | 0 | 5 | 0 | 9 |
| obs. | 8 | 0 | 1 | 0 | 0 |
| R2+6 (Fundin) | 76 | 6 | 34 | 47 | 22 |
| R2+6+4 exp. | 31 | 0 | 5 | 1 | 2 |
| obs. | 7 | 0 | 24 | 0 | 0 |

The absence of R2+4 virulence in fields 1, 2, 3 and 4 is explicable in terms of selection pressure being stronger for other combined virulences. The contrast between fields 4 and 5 is particularly striking in view of the fact that both were close to a field of Sappo. The R0 population is not restricted from the accumulation of R2+4 virulence; the reverse is true of the R2+6 population. The frequencies of R4+5 virulence appear closely similar to those expected. Conversely the observed frequencies of R2+6+4 virulence do not: in field 1 the level of this virulence combination is depressed whilst in field 3, it is inflated. The latter effect may be an artefact due to the presence of a plot of Timmo near to the site of exposure.

Although these data are limited, they suggest that the R group to which the host field belongs may be influencing the observed virulence frequencies on test seedlings by imposing differing selection pressures on members of the pathogen population. In particular, the R2+6 hosts appear to select against non-corresponding virulences.

# MILDEW OF OATS

By I.T. Jones and E. Jones
Welsh Plant Breeding Station, Aberystwyth

A total of forty six samples were received, fifteen of which failed to culture. The remaining thirty one samples were from the following regions - Midlands (11), N. England (6), Wales (1). Scotland (7) and Eire (6) and almost all were from recommended list varieties.

Almost a half of the samples were from varieties with resistance derived from Cc4146, two were from Mostyn (9065 Cn resistance) and the remainder from varieties with no known genes for resistance i.e. Selma, Astor, Maris Quest etc.

Four races, 2,3,4 and 5 were identified which means that all seedling resistance factors now available in commercial varieties are being overcome.

Due to the preponderance of samples from varieties with resistance derived from Cc4146 (Maris Tabard, Maris Oberon, Nelson, Margam), and the increasing area occupied by these newer varieties, the incidence of Races 3 and 5, which overcomes this resistance, showed a further increase compared with the previous year (55% of total samples). Moreover, Race 5 which has the wider spectrum of virulence, attacking both Cc4146 and 9065 resistances has become for the first time the most frequently identified race. It was also detected for the first time on material from Scotland and Eire, on Maris Tabard and Maris Oberon respectively. Samples from varieties with no known major genes e.g. Selma were found to be infected with this race, possibly indicating that it is able to compete satisfactorily with the less complex races.

On the other hand, Race 3, which attacks Cc4146 but not 9065Cn was only detected on varieties with Cc4146 resistance.

The incidence of Race 2, the simplest of the four races (avirulent on both Cc4146 and 9065 Cn) increased from one sample in 1975 (from Inverness) to six samples in 1976 survey. These again came from varieties with no known resistance factors, and only from locations in Eire and Scotland. Race 4 (virulent on Mostyn 9065 Cn resistance, but not on Cc4146) although detected in more than half the samples in 1975 was only identified in eight samples (26% of total samples) in 1976. Most of these came from varieties not possessing the corresponding resistance gene, indicating that this race is well adapted and able to compete with race 2 on varieties such as Selma, Maris Quest, Peniarth. Only four samples from Mostyn were received and the two that were successfully cultured were found to be Race 4, - a very sharp decline in numbers compared with the previous year. This may be partly due to more attention being given to sampling newer varieties carrying the Cc4146 resistance. However, it is of interest to note that the 'severity of attack' on Mostyn (when it is noted on the collector's form) is markedly less than on the newer varieties with Cc4146 resistance (e.g. Maris Tabard, Maris Oberon, Nelson). This confirms other information that Mostyn has a relatively high level of background adult plant resistance which is more effective against Race 5 than that of several of the more recently introduced varieties.

# RHYNCHOSPORIUM OF BARLEY

By ELWYN JONES
Welsh Plant Breeding Station, Aberystwyth.

Forty one samples were received from the winter varieties Maris Otter (3 samples) and Astrix (1) and from the spring varieties Abacus (4), Golden Promise (6), Armelle (1). Midas (2), Maris Mink (10), Hassan (2), Ark Royal (2), Aramir (3) Clermont (2), Verunda (2), Lofa Abed (1) and one each from two breeding lines. Sixteen samples came from Scotland, six from Ireland, three from Wales and the remainder from England, mainly from the North. Seven samples of race UK 2 were identified and 29 of race UK 1; five samples failed to culture.

VARIETAL DIVERSIFICATION: YELLOW RUST OF WHEAT AND BARLEY MILDEW

The following two papers were sent to the testing authorities in England & Wales, Scotland and Northern Ireland, and to the Agricultural Development and Advisory Service.
The information updates that given in the 1975 PRS Annual Report.