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International testing of incomplete resistance against brown rust (Puccinia recondita) in IPHR wheat lines

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Abstract

Promising wheat lines from FAO's International Program for Horizontal Resistance (IPHR) in Brazil and Zambia were tested in the Netherlands against brown rust *(Puccinia recondita* f.sp. *tritici).* Race nursery tests were performed on isolated field plots using five monopustular isolates from the Netherlands representing at least four races. Mature plants of several lines showed high incomplete resistance. For most lines, the reactions to the different races showed a high uniformity. Apparently, lines selected according to the IPHR principles can perform well when exposed to brown rust isolates to which they have not been exposed during selection.

Introduction

The International Program for Horizontal Resistance (IPHR) of the United Nations Food and Agriculture Organization (FAO) initiated new wheat breeding programs in Zambia and Brazil to obtain horizontal resistance by novel methods (Robinson and Chiarappa, 1977; Van der Graaff, 1979; Robinson, 1976). Results were published by De Milliano (1983) for Zambia and Beek (1983) for Brazil.

The present authors use the term incomplete resistance, because that is what they could see and measure. They hope that selection for incomplete resistance brings them nearer to the ideal of horizontal resistance. Incomplete resistance is a form of resistance which does not completely inhibit reproduction of the pathogen (Eskes, 1983).

Some of the most promising IPHR lines with incomplete resistance to brown leaf rust *(Puccinia recondita* f.sp. *tritici*), originating from IPHR programs in Zambia and Brazil, were tested in the Netherlands for incomplete resistance to Dutch brown rust isolates.

Materials and methods

Race nurseries. Adult wheat plants were tested in the field in isolated plots against unipustular rust isolates (Table 1) using the race nursery technique (Zadoks, 1961, 1963, 1966). Each plot contained a number of test lines in duplicate and a spreader,

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Table 1. Characteristics of the Dutch brown rust isolates used for testing.

Number	Source	Location	Year	Accession
1	Marksman	Wieringerwerf	1981	1051
2	Felix	Noordoostpolder	1967	0032
3	Flamingo	Oude Tonge	1967	1037
4	(unknown)	Laboratory	1967[1]/1981[2]	1060
5	Clement	Zuidelijk Flevoland	1981	1084

[1] Mixture.
[2] Single spore culture.

all planted in small hills. The spreader cultivar (Rubis) was inoculated early in the season and then the epidemic developed naturally within the plot. Though plots were at least 30 m apart, cross-contamination could not be excluded. Cross-contamination of plots and natural infection from elsewhere could be recognized timely. The field tests were performed in the Netherlands, in the polder Zuidelijk Flevoland, in 1982 and 1983.

Wheat lines. IPHR lines from Brazil and Zambia were tested together with commercial cultivars grown in the Netherlands. Only the differentials need to be mentioned here: Clement, Felix, Flamingo and Marksman, all winter wheats. The IPHR lines were spring wheats. There is no evidence that the difference between winter and spring habit seriously affected the results of the tests. As most IPHR lines descended from non-European spring wheats, several of CIMMYT origin, and the differentials were European winter wheats, the two groups may represent different gene pools.

Of the Zambian entries, four lines originated from 190 single crosses and underwent a mild positive selection in early generations (code MIL02). Eight lines were derived by pedigree selection following two composite crosses, using male gametocide techniques (scenario's 3, 4 and 7 by De Milliano, 1983). Four of these lines received a mild selection for incomplete resistance to brown rust (code MIL04), and four had received hardly any selection (code MIL03). None of the twelve lines had been exposed to severe brown rust epidemics in Zambia as these did not occur during the period of selection. In the 1982 trial, the seed of all lines had passed through at least five generations of selfing since the last cross (De Milliano, 1983).

The Brazilian entries had different origins. Line 107 is a selection from a landrace called Casquinho. The other five lines are derived from bulk mixtures of 8 to 18 Brazilian cultivars without known vertical resistance against brown rust. After one or more composite crosses, using male gametocide techniques, pedigree selection was applied. Main-season crops were used for selection and off-season crops for multiplication. Line 54 was selected after two, the other lines after three selection cycles.

Brown rust. In Brazil and Zambia the wheat lines were exposed to local rust populations. Most probably, these populations differed widely between the two countries. Furthermore, each population may have varied in genetic composition over the years. For the race nursery tests in the Netherlands, unipustular isolates (Table 1) were used to inoculate potted spreader plants in the laboratory. One day after inoculation they were planted in the field. In 1983, the plots received additional spray inoculations to compensate late planting due to adverse weather conditions. Presumably, these isolates, collected in the Netherlands, are genetically related.

Other pathogens. Spontaneous infection by yellow stripe rust *(Puccinia striiformis)* and powdery mildew *(Erysiphe graminis)* occurred. In 1983, ethirimol was sprayed at a rate of 1 l ha^{-1} to control mildew. Ethirimol does not seem to affect brown rust. Brown rust readings in 1983 may have been affected to some degree by the other diseases.

Disease assessment. Rust severity was assessed in percent of living leaf area affected, using the B-scale of Zadoks and Schein (1979, p. 254). Infection type was assessed using a customary scale with six classes, O, R, MR, M, MS, and S. At the time of assessment, development stages varied from DC 68 to 71 for Brazilian, DC 71 to 75 for Zambian lines and DC 65 to 77 for the differentials (Zadoks et al., 1974). Readings from two independent observers were averaged over two observation days and transformed into relative disease values (RDIS) after assigning the value 100 to the average of the susceptible check Rubis. The relative resistance (RRES) is calculated as RRES = 1. – RDIS (Zadoks, 1972). RRES values from successive observation days were averaged (MRRES).

Uniformity. Comparing RRES values for one cultivar or line tested with different isolates, the value W represents the difference between the highest and lowest RRES. The uniformity index U for that cultivar or line is U = 1. – W.

Results

In accordance with the above definitions, the susceptible check Rubis always has a RRES = O. (Fig. 1) with a uniformity index U = 1. Severities at the second observation day varied from 60 to 85 in 1982 and from 85 to 97 in 1983, thus indicating high infection pressure. The differentials had RRES values between 0.18 and 0.67 for their compatible isolates, 1: Marksman, 2: Felix, 3: Flamingo, and 5: Clement, respectively. Isolates 1 and 2 probably belong to the same field race.

MRRES values for the Brazilian lines varied from 0.70 to 0.98. Typical examples are shown in Fig. 1. Lines 82040 and 82403, with three selection cycles, show high MRRES and high U values. Line 54, with two selection cycles only, had lower MRRES and U values. MRRES values for the Zambian lines varied from 0.54 to 0.99, and some lines, in particular those with a mild selection during several selection cycles, combined high MRRES with high U values.

The susceptible check always had infection type S. Differentials had S to MS types for compatible isolates. The Brazilian lines varied from R (line 107) to S (line 82371). The Zambian lines had a narrower range of reaction types; they varied from R (MILO3-14) to about M (MILO2-4).

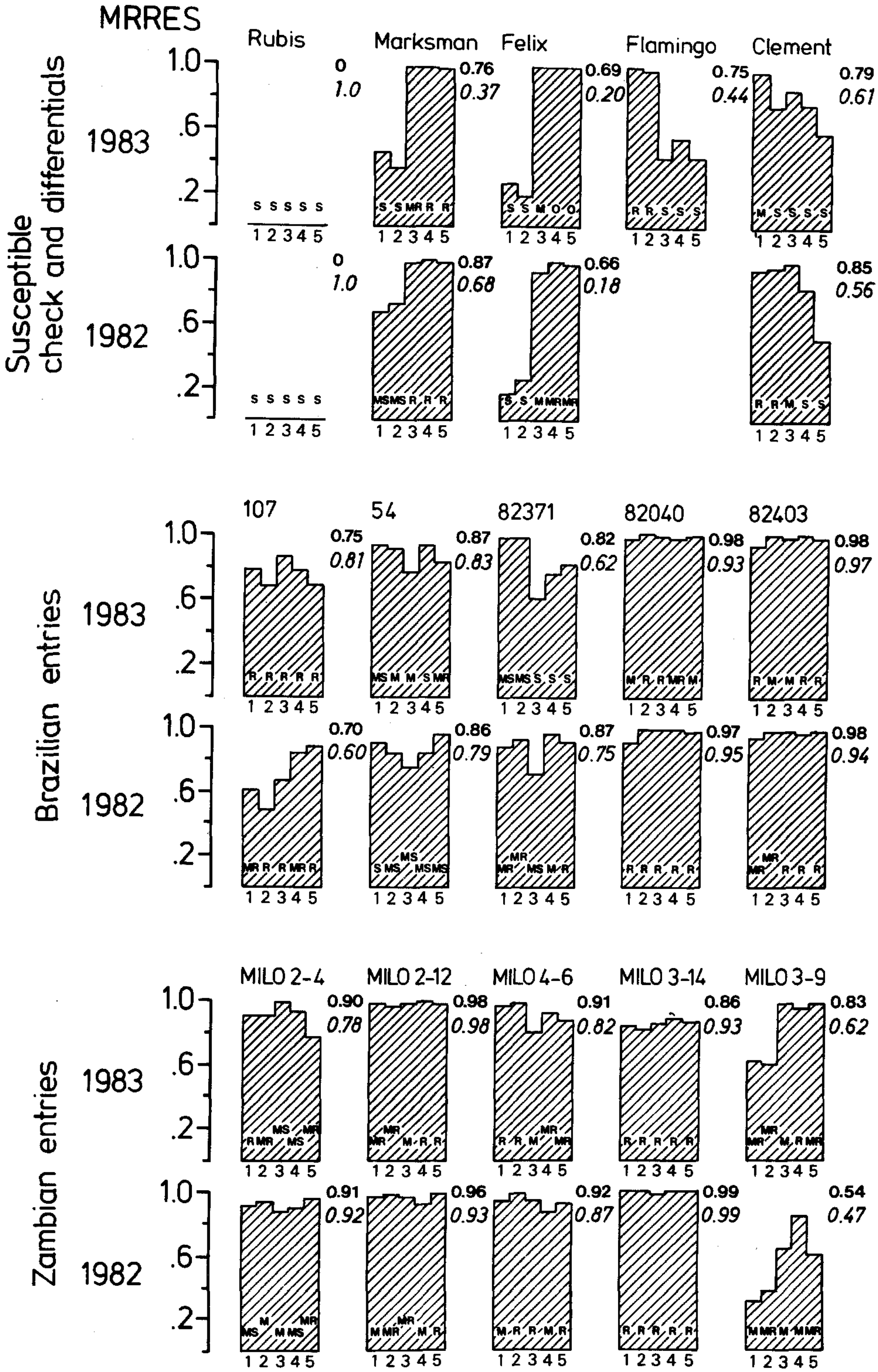
MRRES
Susceptible check and differentials
Brazilian entries
Zambian entries
1983
1982
1.0
.6
.2
1 2 3 4 5
Rubis
Marksman
Felix
Flamingo
Clement
0
1.0
0.76
0.37
0.69
0.20
0.75
0.44
0.79
0.61
0.87
0.68
0.66
0.18
0.85
0.56
107
54
82371
82040
82403
0.75
0.81
0.87
0.83
0.82
0.62
0.98
0.93
0.98
0.97
0.70
0.60
0.86
0.79
0.87
0.75
0.97
0.95
0.98
0.94
MILO 2-4
MILO 2-12
MILO 4-6
MILO 3-14
MILO 3-9
0.90
0.78
0.98
0.98
0.91
0.82
0.86
0.93
0.83
0.62
0.91
0.92
0.96
0.93
0.92
0.87
0.99
0.99
0.54
0.47

Fig. 1. Test results of brown rust *(Puccinia recondita)* on wheat lines from IPHR programmes. Top rows show susceptible check and differentials, middle rows Brazilian and bottom rows Zambian lines. Along the horizontal axis the rust isolates are indicated by the numbers 1 to 5 (Table 1). Along the vertical axis the mean relative resistance MRRES is indicated. MRRES per line-year-isolates combination is shown in bold figures, uniformity U in italics. O, R, M, and S indicate reaction types.

Discussion

Multilocational, intercontinental tests of wheat, also for horizontal resistance, have been common practice since may years (Stubbs, 1977), but this is the first report on such tests of IPHR lines. Race nursery tests were satisfactory for testing adult plant resistant of wheat against yellow rust (Zadoks, 1961; Stubbs, 1977; Stubbs et al., 1974) and brown rust (Zadoks, 1966). Obviously, wheat growing conditions differ widely between Brazil, Zambia and the Netherlands (Fig. 2). Genotype-environment (temperature, daylength) interactions may have affected the results. Reciprocal tests, testing all wheat lines in all three countries, though desirable, could not be realized.

In Zambia, brown rust occurs annually but the disease is seldom severe. Selection for resistance is necessary and possible, especially after artificial infection with local rust material (De Milliano, 1983). In Brazil, in the state of Rio Grande do Sul, brown rust is very serious, and selection for resistance in the field is possible and absolutely necessary. High levels of incomplete resistance were obtained in both countries, but uniformity could not be tested in these countries as no pure races were available. For some selections, incomplete resistance and uniformity showed to be satisfactory in the Netherlands, far from the locality of origin.

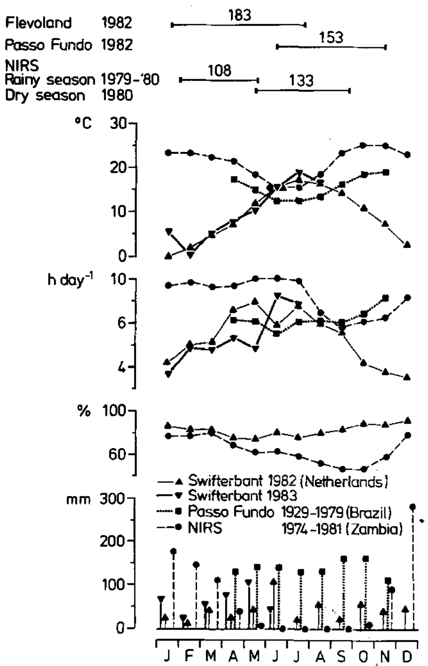

Fig. 2. Monthly weather data from Brazil, Zambia and the Netherlands. From top to bottom: cropping periods of wheat in days from sowing to harvest, mean air temperature in °C, sunshine duration in hours per day, relative humidity of the air in percent, and monthly total rainfall in mm.

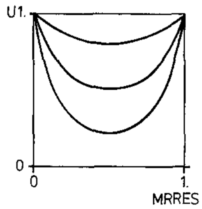

Fig. 3. Hypothetical parabolic relationship between uniformity U and mean relative resistance MRRES at three levels of uniformity.

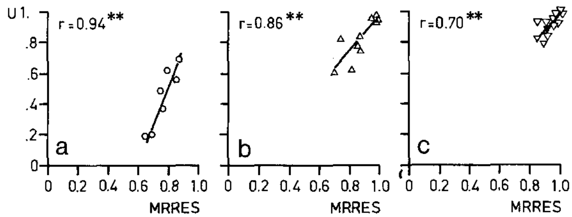

Fig. 4. The relationship between uniformity U and mean relative resistance MRRES. Data pairs from 1982 and 1983. (a) four differentials, (b) five Brazilian lines, (c) six Zambian lines. r = Spearman's correlation coefficient, significant at $p < 0.01$.

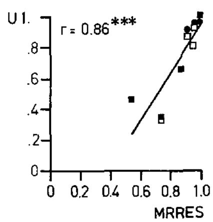

Fig. 5. The relationship between uniformity U and mean relative resistance MRRES. Data pairs from twelve Zambian lines tested in the Netherlands in 1982. ■ = MIL02 lines, □ = MIL03 lines, ● = MIL04 lines. r = Spearman's correlation coefficient with $p < 0.001$.

It should be noted that incomplete resistance (RRES) and uniformity (U) are expected to have a parabolic relationship (Fig. 3). Figs 4 and 5 approximate that relationship in the right hand leg of the parabola by linear regression.

Lines having passed a mild selection for incomplete resistance during several selection cycles, such as some MIL02 lines and the lines 82040 and 82403, were relatively good. However, high levels of relative resistance and uniformity could be obtained after a 'simple cross' as with other MIL02 lines.

The Brazilian and Zambian entries showed M, MS or S reactions against local rust populations in the respective areas of origin. When tested in the Netherlands, they tended toward R reactions. The change may be due either to genotype-environment interactions or to hitherto undetected major genes for high incomplete resistance, eventually approaching hypersensitivity.

No tests exist that decisively prove the absence of vertical resistance genes. In the present case, these could have conditioned a high level of resistance, as shown elsewhere (e.g. Turkensteen, 1973). The best way to demonstrate the possible presence of horizontal resistance is exposing the selected lines to rust isolates to which they have not been exposed during their selection. The results were positive, but such results should not be generalized lightly. Continued multilocational testing is needed. The authors are of the opinion that their results represent the state of the art in IPHR breeding in a fair way. They assume that, for the time being, their results should be ascribed to horizontal resistance sensu Van der Plank (1968).

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Samenvatting

Internationale toetsing op onvolledige resistentie tegen bruine roest (Puccinia recondita) bij IPHR tarwelijnen

Veelbelovende tarwelijnen uit het Internationale Programma voor Horizontale Resistentie (IPHR) van de FAO in Brazilië en Zambia werden in Nederland getoetst tegen bruine roest *(Puccinia recondita* f.sp. *tritici).* Hierbij werd gebruik gemaakt van de fysiovelden-techniek. Geïsoleerde fysiovelden werden geïnoculeerd met vijf Nederlandse isolaten, ieder afkomstig van een sporenhoopje. Deze vijf isolaten vertegenwoordigden ten minste vier fysio's. Bij verscheidene lijnen vertoonden de volwassen planten een hoge mate van onvolledige resistentie. De meeste lijnen vertoonden in hun reactie op de verschillende fysio's een hoge mate van uniformiteit. Kennelijk kunnen lijnen, geselecteerd volgens de beginselen van het IPHR, goede resultaten geven wanneer zij getoetst worden met roest-isolaten, waaraan zij tijdens het selectieproces nooit zijn blootgesteld.

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