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CONTENTS

EDITORIAL

The Cereal Rusts Bulletin was founded to provide rapid publication of research results and surveys of interest to rust workers everywhere. The continuation of the Bulletin depends on a regular supply of suitable articles for publication and many more contributions are required to ensure its future.

Although the Bulletin is published only twice each year, publication of articles often occurs within six months of submission. The Bulletin has a wide circulation amongst rust workers throughout the world. There are no 'page charges' and authors are supplied with 25 free reprints of their articles. Additional reprints can be ordered at a reasonable cost.

Contributions, which should be set out in the form used in recent issues of the Bulletin, should be sent to me as soon as possible, by airmail if necessary, at the address below.

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STANDARD RACES AND VARIANTS (BIOTYPES) OF *Puccinia recondita* f.sp. *tritici* IDENTIFIED IN ITALY IN 1977, EFFECTIVENESS OF SOME RESISTANCE GENES AND GREENHOUSE TESTS OF VARIETIES OF DURUM WHEAT (*Triticum durum* DESF.) AND BREAD WHEAT (*Triticum aestivum* L.)

BY MARIA PARADIES

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For the identification work carried out in 1977 to follow the evolution of Italian populations of *Puccinia recondita* Rob. ex Desm. f.sp. *tritici* Erikes *et* Henn., the reactions of standard differential wheats were studied in the greenhouse as well as those of 4 additional varieties considered resistant in Italy and in other countries (Cariello *et al*., 1977) and of 8 additional near-isogenic wheat lines (Bošković and Browder, 1976).

Durum and bread wheats, some of which are already cultivated in Italy and some which have been recently developed were also tested in the greenhouse towards some *P. recondita* races showing interesting pathogenic characters.

MATERIALS AND METHODS

Rust races were identified according to the key by Johnston and Browder (1966), as described previously (Paradies *et al*., 1977).

Greenhouse testing was performed at 18-25^{o}C and 60-80% relative humidity.

RESULTS AND DISCUSSION

From the 112 *P. recondita* samples from single plants of durum and bread wheat, collected in 1977 for the most part in different localities of Central

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Table 1. Physiologic races of P. recondita identified in Italy in 1977

Physiologic races	Total no. of isolates	% total isolates
11	8	5.3
18	4	2.6
21	6	4
38	4	2.6
45	5	3.3
57	12	8
77	40	26.6
122	4	2.6
130	3	2
140	10	6.6
141	8	5.3
144	6	4
155	3	2
163	8	5.3
220	26	17.3
223	3	2
	150	100

Table 2. Behaviour of 4 additional varieties and 8 near-isogenic lines when inoculated in greenhouse with 112 P recondita samples from durum and bread wheat single plants collected in Italy in 1977.

Races and biotypes	Elia	Ardito Klein	Klein Anivers	(Lr 19) Agatha	(Lr 1) Tc^6 x Centenario	(Lr 2a) Tc^7 x Webster	(Lr 2d) Prel.^{6}x Loros	(Lr 3) Tc^6 x Democrat	(Lr 9) Transfer x Tc^6	(Lr 10) Tc^6 x Exchange	(Lr 17) Tc^6 x Klein Lucero	(Lr 18) Tc^7 x Africa 43	Total no of isolates	% total isolates
11	R	R	S	R	R	R	S	R	R	S	R	S	8	5.3
18	R	S	S	R	R	S	S	S	R	S	R	S	4	2.6
21	R	R	S	R	S	S	S	S	R	R	R	S	5	3.3
21/1	S	S	S	S	S	S	S	S	R	R	S	S	1	0.6
38	R	S	S	R	R	R	S	R	R	S	R	S	4	2.6
45	R	R	S	R	R	S	S	S	R	S	R	S	5	3.3
57	R	R	S	R	R	S	S	S	R	S	R	S	12	8
77	R	S	S	R	S	S	S	S	R	S	S	S	20	13.3
77A	R	S	S	S	S	S	S	S	R	S	S	S	1	0.6
77E	S	S	S	R	S	S	S	S	R	S	S	S	18	12
77EA	S	S	S	S	S	S	S	S	R	S	S	S	1	0.6
122	R	R	S	R	S	S	S	S	R	S	S	S	4	2.6
130	R	R	S	R	S	R	S	S	R	S	R	S	3	2
140	R	R	S	R	R	S	S	S	R	S	R	S	10	6.6
141	R	R	S	R	R	R	S	S	R	S	S	S	8	5.3
144	R	S	S	R	S	R	S	S	R	S	S	S	6	4
155	R	S	S	R	R	R	S	R	R	S	R	S	3	2
163	R	R	S	R	R	R	S	R	R	S	R	S	8	5.3
220	R	R	S	R	R	S	S	R	R	S	R	S	25	16.6
220/1	R	S	S	R	R	S	S	R	R	S	R	S	1	0.6
223	R	S	S	R	R	R	S	R	R	S	R	S	3	2
													150	100
A	3	11	21	3	9	13	21	14	0	19	8	21		
B	20	62	150	3	59	107	150	98	0	144	59	150		
C	13.3	41.3	100	2	39.3	71.3	100	65.3	0	96	39.3	100		

A = No. of virulent races and biotypes
B = Total no. of virulent isolates
C = % total isolates
R = Resistant; S = Susceptible

and South Italy, 150 isolates of the pathogen were obtained, and 16 physiologic races, together with 5 variants of standard races, were identified (Tables 1 and 2).

A comparison of these results with those obtained in previous years (Cariello et al., 1977; Paradies et al., 1977) seems to indicate that the racial composition of leaf rust in Italy is evolving. Race 77 occurred for the first time fairly frequently (26.6%) in our isolations this year. This race, first found in Italy in 1953, appeared only occasionally in subsequent years with a lower than 4% frequency (Basile, 1971, Basile et al., 1971; Cariello et al., 1977) and it was not identified in our sampling of 1976 (Paradies et al., 1977). Race 220, already found by Salazar in Spain in 1964 (Johnston and Browder, 1966), has been identified for the first time in Italy in 1977. Three biotypes (21/1, 77EA and 77A) attacked also Agatha (CI 14048) which carries the resistance gene Lr 19 (Browder, 1972) and which was resistant to 98% of the isolates (Table 2). This variety was also infected in 1975 by some biotypes, representing 10% of the isolates collected (Cariello et al., 1977).

The variety Elia (T. aestivum), obtained by crossing Est Mottin and Libero, was infected by three biotypes (21/1, 77E and 77EA) and showed resistance towards 86.7% of the isolates. This variety has been always considered very resistant in Italy (Zitelli and Vallega, 1970) For instance, in 1974-75 it proved resistant to all isolates except one biotype of race 77 (Cariello et al., 1977). Ardito Sel. Klein was infected by 41.3% and Klein Aniversario by 100% of the isolates.

Amongst the near-isogenic lines tested, (Transfer x Tc^6) RL 6010, which carries resistance gene Lr 9 (Samborski, 1963), was resistant (reaction type 0) to all samples of P. recondita tested in the greenhouse. The gene Lr 9 is therefore very useful and is perhaps the most effective gene so far tested; it has so far been overcome only by one isolate in North American (Shaner et al., 1972) and by one biotype of race 187 in Italy (Cariello et al., 1977).

The genes Lr 1 (Tc^6 x Centenario) and Lr 17 (Klein Lucero x Tc^6) were less effective, being overcome by 39.3% of the isolates. Lr 3 (Tc^6 x Democrat) (overcome by 65.3% of the isolates), and Lr 2a (Tc^7 x Webster) (71.3%) and Lr 10 (Tc^6 x Exchange) (96%) are therefore of less value to breeders. The genes Lr 2d ($Prelude^6$ x Loros) and Lr 18 (Tc^7 x Africa 43) were completely ineffective. The same lines, tested in 24 European and Mediterranean countries, showed comparable behaviour, whereas in other countries, such as U.S.A. and Canada, the corresponding virulence genes occur less frequently (Bošković and Browder, 1976).

Varieties and selections of durum wheat and bread wheat which are already cultivated in Italy and were bred recently for resistance to races 57, 140, 141 and 220 have been tested in the greenhouse. It seems evident that the work performed in Italy to improve the resistance of durum wheat towards P. recondita has yielded satisfactory results. In fact Creso proved resistant to all races tested, as did Valgerardo, Valaniene, Valnova, Sansone 201F, Valnera, Valselva, Giorgio 324, Giorgio 449-1. The performance of the bread wheats was less satisfactory.

CONCLUSIONS

The study of 112 samples of P. recondita has shown some interesting changes in the racial composition of the rust populations present in Italy during 1977. Amongst the 16 standard races identified, 77 and 220 were the most common, with 35.7 and 23.2% of the samples respectively. A similar increase in prevalence of race 77 has already been noticed in central and oriental Europe and in other Mediterranean countries.

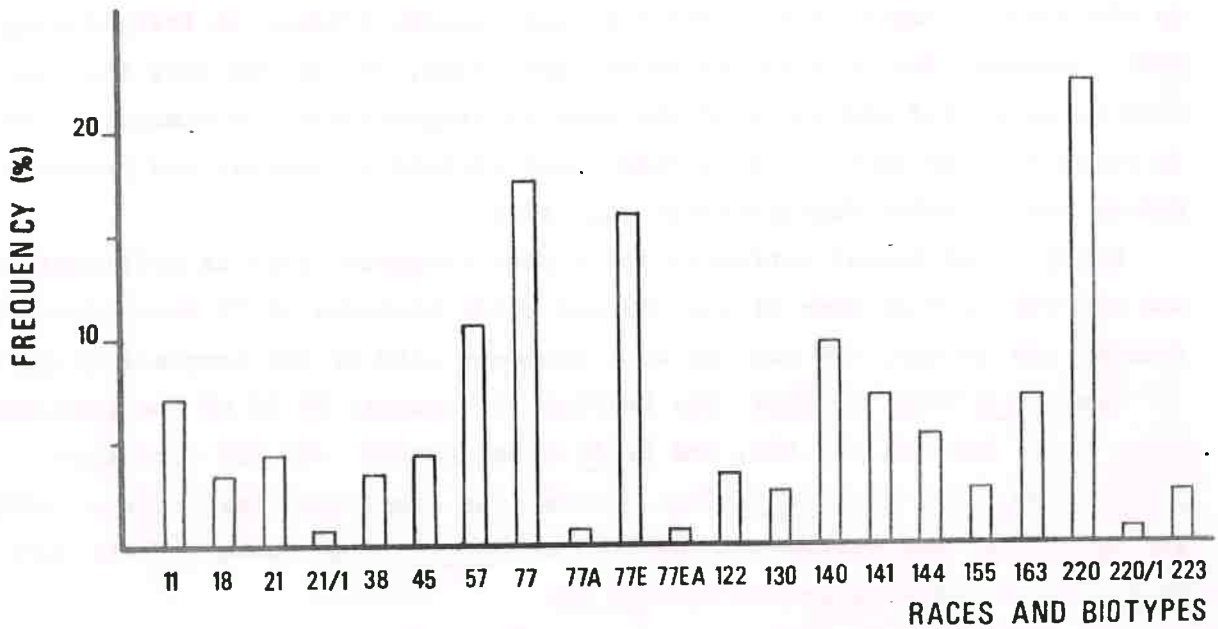
Using 4 additional varieties and 8 near-isogenic lines as differentials, one biotype each of race 21 and 220 and three biotypes of 77 were identified. Amongst the latter, 77E was the most frequent (16% of the samples) (Fig. 1).

Gene Lr 1 from Malakof was ineffective against 39.3% of the isolates; Lr 2c from Brevit (46.6%), and Lr 2b from Carina (53.3%) were also ineffective. The gene Lr 2d from Loros was completely ineffective (100%) and Lr 3 from Mediterranean (85.3%), and Lr 11 from Hussar (74%) were only slightly more effective than Lr 2d.

The near-isogenic line (Transfer x Tc^6) RL 6010, carrying the gene Lr 9, was resistant to all isolates: Agatha, carrying the gene Lr 19, was also very resistant, being susceptible to only 2% of the isolates. The variety Elia was susceptible to 13.3% of the isolates whereas the following varieties were susceptible to many isolates: Klein Aniversario (100%), $Prelude^6$ x Loros (100%), Tc^7 x Africa 43 (100%), Tc^6 x Exchange (96%), Tc^7 x Webster (71.3%) and Tc^6 x Democrat (65.3%).

The study of the behaviour of some varieties of durum wheat and bread wheat towards four races of P. recondita, which are interesting because of their behaviour in Italy in the last few years, has demonstrated the very high resistance of some varieties of durum wheat. On the whole, bread wheats were less resistant than durum wheats.

Fig. 1. Frequency (%) of physiologic races and biotypes of P. recondita identified in Italy during 1977.



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INTERACTIONS BETWEEN U.K. ISOLATES OF *Puccinia recondita tritici* AND THATCHER WHEAT LINES WITH SINGLE RESISTANCE GENES

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An increase in the prevalence of brown rust of wheat, caused by *Puccinia recondita* Rob & Desm.f.sp. *tritici* Eriks & Henn. in England in the early 1970s resulted in the initiation of surveys of virulence in the pathogen population by the author under the auspices of the U.K. Cereal Pathogen Virulence Surveys. A range of virulences has been detected in the pathogen population corresponding to both seedling and adult-plant resistances in U.K. wheat cultivars which were chosen to assess pathogen virulence.

For surveys of *P. recondita* virulence in Canada, the use of a series of wheat backcross lines which carry specific single genes for leaf rust reaction (Lr genes) was begun (Samborski, 1968) to replace the old standard set of differential cultivars (Dyck and Samborski, 1968). These lines have been periodically added to and now comprise thirty-two Thatcher-type lines carrying single seedling or adult-plant resistances (Table 1). Seed of these lines was kindly supplied by Dr. D.J. Samborski, Agriculture Canada, Winnipeg, for tests involving standard U.K. isolates of *P. recondita*. These tests, the results of which are presented here, were carried out to ascertain whether corresponding virulences were present in the U.K. population and also to allow comparisons to be made with pathogen populations from other parts of Europe where workers are utilizing these resistances to monitor pathogen virulence.

PROCEDURES

Standard U.K. isolates of *P. recondita* tested were:-

1. WBRS-74-2. Maris Huntsman virulent (Clifford and Clothier, 1975)
2. WBRS-74-11. Maris Fundin virulent (Clifford and Clothier, 1975)
3. WBRS-77-15. Clement, Aquila, Maris Huntsman, Sportsman virulent (Clifford, Jones and Priestley, 1979)

Table 1. Single gene lines for leaf rust resistance

Gene	Pedigree
Lr 1	Thatcher^6 x Centenario (R.L. 6003)
Lr 2a	Thatcher^6 x Webster (R.L. 6016)
Lr 2b	Thatcher^6 x Carina (R.L. 6019)
Lr 2c	Thatcher^6 x Loros (R.L. 6047)
Lr 3	Thatcher^6 x Democrat (R.L. 6002)
Lr 3bg	Bage x Thatcher^8 (R.L. 6042)
Lr 3ka	Thatcher^6 x Aniversario (R.L. 6007)
Lr 9	Transfer x Thatcher^6 (R.L. 6010)
Lr 10	Thatcher^6 x Exchange (R.L. 6004) 'L' gene
Lr 11	Thatcher x Hussar (R.L. 6053)
Lr 12	Exchange x Thatcher^6 (R.L. 6011) adult-plant resistance
Lr 13	Manitou (Thatcher type) adult-plant resistance
Lr 14a	Selkirk x Thatcher^6 (R.L. 6013)
Lr 14b	Thatcher^6 x Maria Escobar (R.L. 6006)
Lr 15	Thatcher^6 x Kenya W1483 (R.L. 6052)
Lr 16	Thatcher^6 x Exchange (R.L. 6005) 'E' gene
Lr 17	Klein Lucero x Thatcher^6 (R.L. 6008)
Lr 18	Thatcher^7 x Africa 43 (R.L. 6009)
Lr 19	Thatcher^7 x Tr (Agropyron elongatum) - Translocation 4 from Dr. D. Knott) (R.L. 6040)
Lr 21	Thatcher^6 x R.L. 5406 (Tetra Canthatch x *Ae. squarrosa* var. *meyeri* R.L. 5289) (R.L. 6043)
Lr 22	Thatcher^6 x R.L. 5404 (Tetra Canthatch x *Ae. squarrosa* var. *strangulata* - R.L. 5271) adult-plant resistance (R.L. 6044)
Lr 23	Lee 310 x Thatcher^6 (R.L. 6012)
Lr 24	Thatcher^6 x Agent (R.L. 6064)
Lr B	Thatcher^6 x Carina (R.L. 6051)
Lr EG (*Lr 11*)	Thatcher^6 x El Gaucho (R.L. 6048)
Lr T	Thatcher^6 x Terenzio (1 + gene) (R.L. 6049)
Lr Ech	Exchange x Thatcher^6 (R.L. 6014)
LR ?	Thatcher^6 x PI 58548 (1 + gene) (R.L. 6057)
LR ?	Thatcher^6 x PI 58548 (2 + gene) (R.L. 6058)
Lr	Thatcher^6 x PI 268316 (R.L. 6061)

4. WBRS-77-9. Clement, Aquila, Maris Huntsman, Sportsman, Maris Fundin, Maris Ranger virulent (Clifford *et al*., 1979)

5. WBRS-77-22. Clement, Aquila virulent (Clifford *et al*., 1979)

Tests were carried out on seedlings under glasshouse conditions where temperature was controlled to a daytime maximum of 22^{o} and a nighttime minimum of $7^{o}C$. Daylength was extended to 18 h by use of 400W mercury vapour lamps. Inoculations were carried out in a settling tower using 5 mg fresh uredospores per inoculation and plants were then incubated for 16 h at 15^{o} in a dew chamber before return to the glasshouse. Reaction types were recorded after 14 d using standard conventions. Reaction types 0-2 were classified as resistant (R), 3-4 as susceptible (S) and X-types as intermediates (I) after the proposal of Johnston and Browder (1966).

RESULTS

The responses of the single resistance gene lines of wheat are given in Table 2. The resistance of Lr 12, 13 and 22 is only expressed by adult plants and so no statements can be made concerning corresponding pathogen virulence. The majority of the seedling-expressed Lr genes were effective against some isolates but not others. Only Lr 10, 14b, 23 and the factor(s) in R.L. 6058 were ineffective against all 5 isolates and conversely, virulence to Lr 1, 3 19 and 24 was not expressed by any isolate. Two of the U.K. isolates tested (WBRS-74-2 and 77-22) carried 10 corresponding virulences, whereas 13 were carried by WBRS-77-15, 14 by WBRS-77-9 and 15 were detected in WBRS-74-11. This is in addition to the virulences carried by these isolates which are effective against seedling and adult-plant resistances present in U.K. cultivars.

Of the eight standard differential varieties, three, namely Carina, Brevit and Hussar, were omitted by Basile (1957) because of their erratic behaviour and the remaining five (Mediterranean, Democrat, Malakof, Loros and Webster) were employed by her to regroup all described races into a unified numeration (UN) scheme. It is possible to ascribe UN numbers to the isolates tested here by reference to the backcross lines in Table 1 that carry the particular resistance genes present in those five varieties. Most of the standard differentials were used as donors of Lr genes, with the exception of Centenario which was used instead of Malakof to transfer Lr 1 and Mediterranean (Lr 3) which is omitted but which is represented by Democrat. The responses of the U.K. isolates and their UN race designations are given in Tables 2 and 3.

Table 2. Interactions between U.K. isolates of *Puccinia recondita* and specific wheat leaf rust resistance carriers.

Resistance Gene	Pathogen Isolate WBRS-				
	74-2	74-11	77-9	77-15	77-22
Lr 1	R**	R	R	R	R
Lr 2a	R	S	I	I	R
Lr 2b	R	S	S	I	R
Lr 2c	R	S	S	S	I
Lr 3	R	I	R	R	R
Lr 3bg	–	–	–	–	–
Lr 3ka	R	S	R	R	R
Lr 9	R	R	S	R	R
Lr 10	S	S	S	S	S
Lr 11	R	I	S	S	R
Lr 12*	S	S	S	S	S
Lr 13*	S	S	S	S	S
Lr 14a	S	I	I	S	S
Lr 14b	S	S	S	S	S
Lr 15	R	R	S	R	R
Lr 16	S	I	S	S	S
Lr 17	I	S	S	–	S
Lr 18	S	R	I	I	S
Lr 19	R	R	R	R	R
Lr 21	R	S	I	S	I
Lr 22*	S	S	S	S	S
Lr 23	S	S	S	S	S
Lr 24	R	R	R	R	R
Lr B	S	S	S	S	R
Lr EG	I	S	S	S	S
Lr T	R	S	R	R	R
Lr Ech	S	S	S	S	I
R.L. 6057	–	–	–	–	–
R.L. 6058	S	S	S	S	S
R.L. 6061	S	S	I	S	S

*Adult-plant resistances

**R= Resistant, I = Intermediate, S = Susceptible

Table 3. Interactions between U.K. isolates of *Puccinia recondita* and standard *Lr* gene carriers

Single gene line	Lr 1	Lr 2a	Lr 2c	Lr 3	Lr 3	
Differential	Centenario	Webster	Loros	Mediterranean	Democrat	UN race
WBRS-74-2	R*	R	R	R	R	1
-74-11	R	S	S	S	S	17
-77-9	R	S	S	R	R	19
-77-15	R	I	S	R	R	12
-77-22	R	R	S	R	R	10

*R = Resistant, I = Intermediate, S = Susceptible

DISCUSSION

The most interesting result of these limited tests was the detection of considerable apparently unnecessary virulence in these samples from the U.K. population of *P. recondita tritici*. These virulences appear unnecessary because, as far as is known, the matching host resistances are not present in current or recent U.K. cultivars of wheat and consequently there has been no selective advantage conferred on their carriers. The surveying done to date has not involved the detection of these virulences and so no statements can be made on their relative frequencies in the pathogen population or on the aggressiveness of their carriers. However, it is interesting to note the large numbers of virulences that can be carried by the pathogen with no apparent disadvantage and this is similar to the situation reported by Clifford (1974) for *Puccinia hordei* Otth. on barley. It is also in agreement with Bošković and Browder (1976) who found that all isolates of *P. recondita tritici* tested from the European - Mediterranean region carry five or more virulences when tested on a set of nine different *Lr* gene carriers.

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VARIATION FOR LATENT PERIOD, ONE OF THE COMPONENTS OF PARTIAL RESISTANCE IN BARLEY TO YELLOW RUST, CAUSED BY *Puccinia striiformis*

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SUMMARY

Nine spring barley cultivars with a susceptible infection type were inoculated with *Puccinia striiformis* race 24 at the seedling and adult plant growth stages. At the seedling stage the latent period ranged from 18.1 to 19.5 days at approximately 10°C and from 9.6 to 11.0 days at approximately 20°C. At the adult-plant stage the range was from 12.2 days to 21.5 days for the flag leaves and from 13.0 to 18.7 days for the leaf below the flag leaf. The adult-plant observations made under greenhouse conditions showed a good agreement with resistance evaluated in the field.

INTRODUCTION

Partial resistance has often been suggested as an alternative to the highly race-specific monogenic resistances in the cereal-rusts pathosystems. Partial resistance is characterized by lower infection frequencies, longer latent periods and a reduced sporulation, despite a susceptible infection type (Parlevliet and Van Ommeren, 1975). In barley the latent period (LP) is the most important component of partial resistance to *Puccinia hordei* (Parlevliet and Van Ommeren, 1975). It shows large variation in the adult-plant stage, but only small variation in the seedling phase (Parlevliet, 1975). A similar pattern was observed in rye for *Puccinia recondita* f.sp. *recondita* (Parlevliet, 1977) and in wheat for *P. recondita* f.sp. *tritici* (Parlevliet, unpublished).

A number of barley cultivars with a susceptible infection type to *P. striiformis* were studied to see whether a similar pattern exists in this pathosystem.

MATERIALS AND METHODS

Nine spring barley cultivars were grown in black plastic pots. Seedlings were inoculated about seven days after emergence, when the first leaf was fully expanded. Spores of race 24, diluted with *Lycopodium* spores, were dusted over the plants. One set of seedlings (12 per cultivar) was kept at temperatures around 10°C, another set at temperatures around 20°C. The light conditions were the natural ones prevailing in early March.

Adult plants, five per cultivar, were inoculated when the ears had just emerged. A mixture of spores of race 24 and of *Lycopodium* spores was placed on the surface by touching specific areas with the thumb and index finger dipped in the inoculum. The areas were just below the middle of the flag leaves and the leaves below them on three tillers per plant. During the incubation period the plants were kept at temperatures fluctuating between 16 and 22°C at natural light conditions prevailing in late March.

For each seedling leaf or adult plant leaf, the day at which the first yellowing of the first urediosorus was noted. The mean over all observations per treatment was taken as a measure of the LP.

RESULTS AND DISCUSSION

At the seedling stage the LP varied very little at both temperatures (Table 1) with a difference between cultivar means of only 10%. This is similar to observations in the barley-*P. hordei* system, where the majority of the cultivars vary between 100-112% (Parlevliet, 1975; Parlevliet and Van Ommeren, 1975), and the rye-*P. recondita* f.sp *recondita* system, where the genotypes varied in the seedling stages between 8 and 9 days (Parlevliet, 1977).

In the adult-plant stage there was much more variation between cultivar mean LP values (Table 2). For two cultivars the LP is not indicated; Ramona showed no sporulating infections at all, Tamara too few to obtain a reasonably reliable estimate for LP. The range in variation of cultivar means for LP was considerably smaller for the second leaf than for the flag leaf.

The parallel with the barley-*P. hordei* and the rye-*P. recondita* f.sp. *recondita* systems is again remarkable. In the barley-brown rust system the range is slightly wider, with considerably more cultivars tested; in the rye-brown rust system the range in LP between genotypes was from 8 to 14 days (Parlevliet, 1975; 1977). Similar small cultivar differences in the seedling

Table 1. Latent period in days of some spring barley cultivars in the seedling stage at two temperature ranges when infected with *Puccinia striiformis*, race 24.

Cultivar	Latent period		Mean latent period
	8-12°C	18-22°C	relative to Georgie
Georgie	18.1	9.8	100
Vada	18.3	9.6	100
Volla	18.3	10.0	102
Berac	18.3	10.0	104
Sultan	18.5	10.3	104
Ramona	18.3	10.7	105
Julia	19.5	10.1	106
Tamara	18.8	10.8	107
Drossel	19.5	11.0	110

Table 2. Latent period of some spring barley cultivars infected with <u>Puccinia striiformis</u> race 24, the percentage of inoculated leaves that showed sporulating infections, and the field evaluation for resistance according to the Dutch lists for recommended cultivars.

Cultivar	Latent period				Percentage leaves with infections		Field evaluation*
	In days		Relative to Volla				
	Flag leaf	2nd leaf	Flag leaf	2nd leaf	Flag leaf	2nd leaf	
Volla	12.2	13.0	100	100	100	100	4
Berac	14.5	15.3	119	118	80	80	3 to 4
Vada	15.4	16.0	126	123	93	73	5
Drossel	16.6	16.3	136	125	80	60	5
Julia	16.9	16.6	139	128	87	80	6
Georgie	17.7	16.2	145	125	73	60	5
Sultan	21.5	18.7	176	144	60	87	6
Tamara	–	–	–	–	27	7	8
Ramona	–	–	–	–	0	0	8

*The evaluation for resistance ranges from 1, extremely susceptible, to 10, completely resistant.

stage and relatively large differences in the heading stage have also been observed for the wheat-brown rust system (Parlevliet, unpublished data).

This pattern is apparently not restricted to the cereal rusts. Jones (1978) observed that oat cultivars infected with powdery mildew caused by Erysiphe graminis f.sp. avenae, showed small differences in incubation period at the seedling stage (from 4½ to 6 days), whilst the range was much wider at older plant stages (from 4 to 12 days).

Table 2 also shows that the frequency of inoculated leaves resulting in sporulating infections tended to decrease with increasing LP. Without exception, the non-sporulating leaves were completely free from any macroscopical signs of infection. The reduced chance of successful infection on the inoculated leaf parts could be an indication of a reduced infection frequency, another component of partial resistance. In the barley-brown rust system these two components are strongly correlated (Parlevliet and Kuiper, 1977) and this might also be the case in the barley-yellow rust system.

Another aspect, of practical importance, is the good relationship between the field evaluation for resistance of these cultivars and the greenhouse data for LP and infectivity as shown in Table 2. This again closely follows the barley-brown rust system where the greenhouse data predict the field performance for partial resistance very well (Parlevliet et al., 1980). This greenhouse test, which has to be carried out with adult plants, is rather laborious. Because of this it is not likely to be useful in the early phases of a breeding programme where large numbers of progeny plants or lines have to be screened. It could, however, be useful when only a limited number of lines or cultivars have to be assessed. This is the case in later phases of the breeding programme or when lines or cultivars are considered as potential parents in new crosses.

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EFFECT OF SOLAR RADIATION ON SURVIVAL OF *Puccinia hordei* UREDOSPORES IN NEW ZEALAND

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Species of *Puccinia* have been reported to have different reactions to solar radiation. In their extensive study on wheat rusts, Maddison and Manners (1972) found that *P. striiformis* uredospores were more sensitive to sunlight than those of *P. recondita* or *P. graminis*. Exposure for a complete day in sunny conditions reduced germination percentage of *P. striiformis* uredospores to less than 0.1%, while the equivalent figures for *P. graminis* and *P. recondita* were 10% and 6.7%. Early work by Hwang (1942) had also shown that uredospores of *P. graminis* were more resistant to the effects of sunlight than *P. recondita* and that after 20 h of exposure, *P. graminis* retained 58 - 72% germination. It is unfortunate that in all studies reported in the literature, no measurement of solar radiation were made. This deficiency was noted by Maddison and Manners (1972), who attributed it to the general unavailability of suitable radiation-recording instruments; the apparent differences between their results and those of Hwang (1942) may have been due to differences in incident solar energy.

As part of our research towards developing a computer simulation model of barley leaf rust (Teng *et al.* 1980), information was needed on the effect of solar radiation on uredospore survival after spore liberation but before deposition, and after deposition but before the initiation of germination. The objective of this study was to determine the survival of deposited *P. hordei* uredospores after exposure to ambient solar radiation on selected days of a New Zealand summer. The study was restricted to the summer as this was the time of year that leaf rust had the potential of developing into severe epidemics in New Zealand (Teng *et al.*, 1979).

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MATERIALS AND METHODS

The effect of solar radiation on spore survival was studied using the apparatus described as follows. A metal tank (81 cm long x 41 cm wide x 41 cm high) was filled with water and the coils of a freezing unit immersed to about 10 cm above tank bottom. Water in the tank was stirred by a small twin-blade motor (Type S 30/C, Voss Instruments Ltd., Essex, England). The freezing unit was set at 35°F (1.7°C) and its thermostat placed just beneath a stainless steel tray (41 cm x 20 cm) floating on the water. Freshly collected uredospores from inoculated plants growing in the greenhouse were impacted onto membrane filters using the suction collector of Teng and Close (1977). Replicate sets of 3 filters were placed on the tray at the commencement of each experiment. Temperature on the surface of two filters was measured at 15-min intervals using disc thermocouples ('Disc Thermistors, Type E') connected to a temperature chart recorder (Grant Miniature Temperature Recorder, Type D, Grant Instruments Ltd., Cambridge, England). After specified times of exposure on selected days, three replicate filters were removed in a glass petri dish and stored in a refrigerator at 6°C. On the day following each experiment, germination was assessed after seven hours of incubation of membrane filters on wet filter paper pads at 20°C in the dark. Experiments were conducted on three sunny days (November 10, 1975; December 22, 1975; January 20, 1976) and two cloudy days (November 13, 1975; January 13, 1976) during the New Zealand summer. In all experiments, a control set of filters with uredospores was kept in the dark next to the apparatus and sampled at the same time as the exposed filters. The complete apparatus was sited at Lincoln College (latitude 43°38' S) at an altitude of 27.3 m above sea level.

To study the effect of continuous low radiation intensity on spore survival, freshly collected uredospores were impacted on membrane filters and left on a laboratory bench at 15 - 20°C, 60 - 75% rh and 7000 - 10 000 lx. It was difficult to anticipate the number of filters required and a total of 50 petri dishes, each with two filters, was prepared for the experiment. Daily, two petri dishes were sampled at random and the uredospores tested for germination.

Measurements of solar radiation on days of experiment were made using a solarimeter (Model CM6, Kipp & Zonen, Holland) located on the same roof. The solarimeter provides measurements of incident solar radiation integrated over one hour, in Wh/m^2 (Watt-hour per square metre).

The criterion for assessing survival was spore germination measured as germination percentage. The following working definitions were adopted:

Germination – is considered to have occurred if the germ tube of an uredospore has exceeded the largest diameter of the spore.

Germination percentage – is the number of germinated spores divided by total number of spores in a sample, expressed as a percentage

RESULTS AND DISCUSSION

Spore viability was found to be greatly affected by solar radiation on the three sunny days that spores were exposed – November 10, 1975, December 22, 1975, and January 20, 1976. Using the integrated measures for solar energy provided by the solarimeter, accumulation of 8500 to 9000 Wh/m^2 of exposure completely kills all P. hordei uredospores (Table 1). Concomitant with the decline in germination, a bleaching effect on the orange-brown colour of the uredospores could be detected. On the completely cloudy day of January 13, 1976, no decline in spore viability was found and the accumulated radiation did not exceed 2000 Wh/m^2. However, with the partly cloudy day (November 13, 1975), solar radiation for the day reached 4756 Wh/m^2 and a slight decrease in spore germination was found (Table 1). In all experiments, control spores kept in the dark suffered no loss in germination percentage. There were variations in the ¼-hourly temperature recorded on the surface of the supporting medium (membrane filter), though the apparatus successfully maintained temperatures which were favourable for the rust.

Results of the experiment in which uredospores were exposed to simulated continuous cloudy conditions in the laboratory are in Table 2. Under these conditions, spores of P. hordei remained viable for about 38 days. However, this long period of survival at ground level would be unlikely under field conditions. In a study on wheat stem rust, Mohamed (1960) found that, under glasshouse conditions of 87 – 90°F (30.5°C – 32.2°C) and 3000 – 4000 fc (32 000 – 43 000 lx), dry uredospores survived for a maximum of 11 days. Under simulated field conditions of 85,000 lx – 128,000 lx and average 27°C, Smith (1969) found that dry uredospores of stem rust on wheat foliage had their germination percentage reduced to less than 1% after 15 h exposure. This latter result is of interest as it indicates that experiments using an artificial supporting medium are comparable with those using cereal leaves. Hwang (1942) had previously concluded from his studies that uredospores deposited on cereal leaves, especially on the lower shaded foliage, may remain viable for 'at least four days and probably longer'.

Although previous studies have indicated a limited survival ability of

Table 1. Effect of sunlight on uredospore survival at Lincoln College, New Zealand.

Time of day*	10 November 1975 (sunny)		22 December 1975 (sunny)		13 November 1975 (partly cloudy)	
	Radiation Wh/m^2	Germination % ± SE	Radiation Wh/m^2	Germination % ± SE	Radiation Wh/m^2	Germination % ± SE
0400	0.00		0.00		0.00	
0500	0.00	89.8 ± 6.2	0.00	92.7 ± 6.4	0.00	90.5 ± 7.0
0600	0.48	90.5 ± 4.3	0.06	91.3 ± 6.0	0.01	91.2 ± 6.1
0700	2.55		0.98		0.12	
0800	6.92	85.1 ± 3.9	3.69	91.1 ± 5.1	0.57	90.6 ± 5.7
0900	13.23		8.46		1.44	
1000	21.21		15.11		3.29	
1100	30.40	43.6 ± 3.5	23.45	55.4 ± 4.3	6.69	89.7 ± 6.3
1200	40.34	25.2 ± 2.6	33.06	49.3 ± 4.6	10.53	89.4 ± 6.7
1300	50.42		43.37		17.98	
1400	60.07		54.15		26.40	
1500	68.80	7.4 ± 1.0	63.39	9.2 ± 1.1	32.23	78.7 ± 5.9
1600	76.08		72.89		39.90	
1700	81.56	3.1 ± 0.6	81.08	4.6 ± 0.8	43.92	72.6 ± 5.7
1800	85.12		87.60		45.48	
1900	86.24	0.0 ± 0.0	92.19	0.5 ± 0.4	42.20	71.5 ± 5.5
2000	86.36		94.38		46.51	
2100	86.36	0.0 ± 0.0	95.53	0.0 ± 0.0	46.56	70.8 ± 6.0
2200	86.36		95.56		46.57	70.3 ± 4.8
Mean germination percentage of control spores in dark		88.7 ± 4.3		93.1 ± 6.2		89.9 ± 5.3

*New Zealand standard time

Table 2. Survival of *P. hordei* uredospores under simulated continuous low radiation (cloudy) conditions in the laboratory

Days of exposure	Germination percentage (± S.D.)	Days of exposure	Germination percentage (± S.D.)
0	91.5 ± 3.4	19	34.8 ± 3.1
1	91.3 ± 4.2	20	32.3 ± 3.5
2	90.9 ± 3.7	22	31.5 ± 2.6
3	87.5 ± 5.1	23	11.2 ± 1.8
4	84.6 ± 6.2	24	10.3 ± 0.9
5	78.3 ± 3.2	26	8.7 ± 1.1
6	70.1 ± 5.3	28	5.2 ± 0.8
11	65.6 ± 6.1	30	3.5 ± 0.7
13	44.7 ± 4.6	34	0.8 ± 0.7
16	40.5 ± 3.9	38	0.5 ± 0.6
17	40.4 ± 3.7	40	0.0 ± 0.0
18	35.5 ± 2.9		

uredospores under field conditions at sea level, other studies have shown that when desiccated and in environments of low relative humidity and temperature (such as would occur at high altitudes), uredospores can survive for much longer periods. Kilpatrick *et al.* (1971) for example, reported little loss in viability of *P. graminis* spores stored in liquid nitrogen for ten years and similar results were obtained by Cunningham (1973) for a number of rust species and genera, while Bromfield (1967) found that at 4°C and 10% spore moisture, uredospores of *P. graminis* survived for 1-2 years. Maddison and Manners (1972) have cautioned that when extrapolating results such as those of Kilpatrick *et al.* (1971) and Bromfield (1967) to long-distance spore dispersal, it should be remembered that at higher altitudes, ultra violet radiation constitutes a higher proportion of solar radiation than at sea level. There is evidence to show that the component of solar radiation that kills uredospores is in the ultra violet zone (Hwang, 1942; Maddison and Manners, 1973). Maddison and Manners (1973) further showed that increasing ambient relative humidity increased the sensitivity of *P. striiformis* uredospores to ultra violet radiation and that the effect was temperature-independent. The effect of components of solar radiation on survival of *P. hordei* uredospores was beyond the scope of the present study and the results reported here should be interpreted with this in mind.

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