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LEAF RUST RESISTANCE IN SPRING BARLEY CULTIVARS AND BREEDING LINES

ABSTRACT

A total of 67 barley cultivars and breeding lines were tested for leaf rust resistance were tested with eight differential isolates. These isolates originated from IHAR Radzików collection and were chosen according to their virulence spectra. Among 67 cultivars and breeding lines 41 (61%) showed resistance reaction after inoculation with at least one isolate of leaf rust. In 29 cultivars and breeding lines (43.2%) the presence of specific resistance alleles was postulated. For most tested cultivars and breeding lines (56.8%) it was impossible to postulate the presence of the specific resistance alleles. Twenty six (38.8%) cultivars and breeding lines showed susceptible reaction after inoculation with all isolates used. Four cultivars and breeding lines (NAD 2298, Granal, Barke, BKH 4300) were composed of lines carrying different genes for resistance.

Four different resistance alleles (*Rph3*, *Rph7*, *Rph9* and *Rph12*) were detected alone or in combinations. Among tested cultivars and breeding lines, twenty had one gene for resistance and 8 had combination of different genes for resistance. The most common resistance allele was *Rph12* (19 cultivars and breeding lines). Alleles *Rph9* and *Rph3* were postulated in 4 cultivars and breeding lines. Allele *Rph7* was postulated to be present in only one cultivar Hanka. Different strategies for control of barley leaf rust using resistance genes were discussed.

Key words:

INTRODUCTION

Barley leaf rust, caused by the fungal pathogen *Puccinia hordei* Otth, is an important foliar disease in most regions throughout the world including Europe (Clifford 1985), North America (Griffey *et al.* 1994, Roane 1962, Sharp and Reinhold 1982), Near East (Anikster 1982, 1984, Anikster *et al.* 1992, Brodny *et al.* 1992), New Zeland (Lim and Gaunt 1986, Teng *et al.* 1979), Australia (Park *et al.* 1992) and North Africa (Parlevliet *et al.* 1981, Yahyaoui and Sharp 1987). It is a frequently occuring a barley disease in Poland (Mazaraki and Grabowska 1998). In Central Europe leaf rust ranks second after powdery mildew among the most common diseases of barley (Czembor *et al.* 2006, Dreiseitl and Jurecka 1996, 1997). It appears that the economic importance of barley leaf rust has increased in recent years in central and northwestern Eu-

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rope (Czembor *et al.* 2006, Dreiseitl and Steffenson 2000, Mazaraki and Grabowska 1998, Niks *et al.* 2000). Most probably it is caused mainly by observed increases in fitness of leaf rust populations to cultivar Vada (Niks personal communication)

The use of disease-resistant barley cultivars has been an efficient means for controlling the disease and preventing yield losses. Barley yield losses may reach 30% in susceptible cultivars due to infection by *P. hordei* (Griffey *et al.* 1994, Whelan *et al.* 1997). However the average yield losses of barley due to leaf rust reach usually 10-25% (Niks *et al.* 2000). At present, 19 loci with major genes for resistance to leaf rust are described: *Rph1*, *Rph2bj*, *k*, *l*, *m*, *n*, *q*, *r*, *s*, *t*, *u*, *y*, *Rph3c*, *w*, *aa*, *Rph4*, *Rph5*, *Rph6*, *Rph7g*, *ac*, *Rph8*, *Rph9*, *Rph10*, *Rph11*, *Rph12*, *Rph13*, *Rph14*, *Rph15*, *Rph16*, *Rph17*, *Rph18*, *Rph19*) (Chełkowski *et al.* 2003, Franckowiak 2002, Franckowiak *et al.* 1997, Park and Karakousis 2002, Park *et al.* 2003).

The resistance alleles present in cultivars and breeding lines used in agriculture have to be known in order to interpret interactions between populations of the *P. hordei* and barley. Therefore, tests of the cultivars and breeding lines had to be carried out for identifying alleles for leaf rust resistance. This identification is conducted on the basis of the gene-for-gene hypothesis. Using this hypothesis it is possible to identify such genes by inoculation of plants with pathogen isolates that have a defined, well-known virulence spectrum and the subsequent reading of infection types. This method is commonly used in breeding programmes of barley for resistance to infection by obligate pathogens such as rusts and powdery mildews (Czembor 1996, 2005, Dreiseitl and Steffenson 2000).

The aim of the presented investigation was to identify the leaf rust resistance genes in spring barley cultivars and breeding lines included in Polish official trials.

MATERIALS AND METHODS

Plant material

A total of 67 barley cultivars and breeding lines from Polish register were tested (Table 1). Seed samples of these cultivars were kindly provided by their breeders.

Pathogen

Eight differential isolates of *P. hordei* were used (Table2). These isolates originated from IHAR Radzikow collection and were chosen according to differences in virulence spectra observed on 12 differential cultivars. None of the isolates used was able to differentiate genes *Pa4* from *Pa8* and *Pa1* from *Pa10* and *Pa11*.

Table 1

Sixty seven cultivars and breeding lines of spring barley with their country of origin, status, breeder and year of entry of Polish Cultivar Register (Anonymous 2001)

No	Cultivar	Country of origin	Status of a cultivar	Year of entry in the Register	Breeder
1	2	3	4	5	6
1	Lot	PL	R	1987	ZDHAR Małyszyn
2	Rudzik	PL	R	1987	H. R. Szelejewo
3	Maresi	DE	R	1991	Lochow - Petkus GmbH
4	Edgar	PL	R	1992	ZDHAR Bąków
5	Polo	PL	R	1992	ZDHAR Borowo
6	Rodos	PL	R	1992	ZDHAR Strzelce
7	Rambo	PL	R	1993	ZDHAR Grodkowice
8	Boss	PL	R	1994	ZDHAR Bąków
9	Start	PL	R	1995	ZHR Polanowice
10	Bies	PL	R	1996	H. R. Szelejewo
11	Rabel	PL	R	1996	ZDHAR Smolice
12	Rataj	PL	R	1996	ZDHAR Radzików
13	Rodion	PL	R	1996	ZDHAR Kończewice
14	Atol	PL	R	1997	ZDHAR Strzelce
15	Brenda	DE	R	1998	Semundo Saatzucht GmbH
16	Bryl	PL	R	1998	ZDHAR Bąków
17	Orthega	DE	R	1998	Lochow - Petkus GmbH
18	Rasbet	PL	R	1998	ZDHAR Radzików
19	Refren	PL	R	1998	ZDHAR Borowo
20	Madonna	PL	R	1999	Lochow - Petkus GmbH
21	Scarlett	PL	R	1999	Saatzucht Josef Breun GdbR
22	LP 2.2840	DE	T	1999	Lochow-Petkus
23	NAD 2298	PL	T	1999	SHR Nagradowice
24	NAD 2398	PL	T	1999	SHR Nagradowice
25	Gwarek	PL	R	1999	HR Szelejewo
26	Poldek	PL	R	1999	HR Szelejewo
27	Rastik	PL	R	1999	ZDHAR Radzików
28	Stratus	PL	R	1999	Hod. Roślin Strzelce
29	Sezam	PL	R	2000	SHR Modzurów
30	Prosa	AU	R	2000	Probsdorfer Saatzucht
31	Jersey	NL	T	2000	Cebeco
32	LP 697.94	DE	T	2000	Lochow-Petkus
33	NAD 2799	PL	T	2000	SHR Nagradowice

Table 1

continued

1	2	3	4	5	6
34	NS 96 1114	DE	T	2000	Nordsaat Saatzucht
35	P 7020	AU	T	2000	Probsdorfer Saatzucht
36	Pejas	CZ	T	2000	CEZEA Ceic
37	STH 3499	PL	T	2000	ZDHR Strzelce
38	Forum	CZ	R	2000	HyBriTech
39	Orlik	PL	Re	2000	ZDHAR Bąków
40	Riviera	GB	R	2001	PBI
41	Blask /BKH 3798/	PL	R	2001	ZHR Bąków
42	Granal /NAD 2498/	PL	R	2001	SHR Nagradowice
43	Justina /NS 96 1116	DE	R	2001	Nordsaat Saatzucht
44	Annabell	DE	R	2001	Nordsaat Saatzucht
45	Antek /P 6616/	AU	R	2001	Probsdorfer Saatzucht
46	Barke	DE	R	2001	Saatzucht Josef Breun GdbR
47	BKH 4200	PL	T	2001	HR Smolice
48	BKH 4300	PL	T	2001	HR Smolice
49	BKH 4400	DL	T	2001	HR Smolice
50	CSBA 4369-5	GB	T	2001	Monsanto
51	GS 1848	DE	T	2001	Nordsaat Saatzucht
52	GS 1850SEC 8311X	DE	T	2001	Nordsaat Saatzucht
53	Hadm 52559-95	DE	T	2001	Saatzucht Hadmersleben
54	MOB 2000	PL	T	2001	HR Szelejewo
55	MOB 2100	PL	T	2001	HR Szelejewo
56	NAD 2800	PL	T	2001	Poznańska Hod. Roślin
57	NAD 2900	PL	T	2001	Poznańska Hod. Roślin
58	NAD 3000	PL	T	2001	Poznańska Hod. Roślin
59	POA 2400	PL	T	2001	HR Szelejewo
60	Prestige	GB	T	2001	Monsanto
61	Semu 51153-91 /Hanka/	DE	T	2001	Saatzucht Hadmersleben
62	STH 3600	PL	T	2001	Hod. Roślin Strzelce
63	STH 3700	PL	T	2001	Hod. Roślin Strzelce
64	STH 3800	PL	T	2001	Hod. Roślin Strzelce
65	SW 1562		T	2001	Svalof Weibull
66	Tolar	CZ	T	2001	Plant Select
67	Mobek	PL	Re	2001	H. R. Szelejewo

R - Original cultivar entered in the Register
T- Original cultivar or breeding line entered to the official trials
Re - Original cultivar removed from the Register

Table 2

Differential isolates used and their infection types

Accession name	Accesion number	Gene	Isolates								References
			Ph- 9	Ph-5	Ph-4	Ph-6	Ph-31	Ph-21	Ph-17	Ph-25	
Sudan	CIho 6489	Pa1	4	4	4	4	4	4	4	4	Roane and Starling (1967)
Peruwian	CI 935	Pa2	4	4	4	4	4	4	2	4	Levine and Cherewick, 1952; Starling, 1956
Estate	CI 3410	Pa3	0	4	0	4	4	0	4	4	Henderson, 1945; Roane and Starling, 1967
Gold	CI 1145	Pa4	4	4	0	4	4	4	4	4	Moseman and Reid, 1961; Roane, 1962; Roane and Starling, 1967
Magnif	CI 13860	Pa2+ Pa5	4	1	4	0	0	0	1	4	Frecha, 1970; Yahyaoui and Sharp, 1987
Bolivia	CI 1257	Pa2+ Pa6	4	4	4	4	0	4	4	4	Henderson, 1945; Starling, 1956; Roane and Starling, 1967, 1970
Cebada Capa	CI 6193	Pa7	0;	0;	0;	0;	0;	0;	0;	0;	Johnson, 1968; Starling, 1956; Nover and Lehman, 1974; Parlevliet, 1976
Egypt 4	CI 6481	Pa8	4	4	0	4	4	4	4	4	Levine and Cherewick, 1952; Tan, 1977
HOR 2596	CI 1243	Pa9	4	4	4	4	4	1	4	4	Tan, 1977
Cliper C8	None	Pa10	4	4	4	4	4	4	4	4	Feuerstein *et al*., 1990
Cliper C67	None	Pa11	4	4	4	4	4	4	4	4	Feuerstein *et al.*, 1990
Triumph	PI 290195	Pa12	4	4	4	4	4	0;	4	4	Walther, 1987; Jin *et al*. 1993

Testing procedure

This study was carried out in the IHAR Radzików greenhouse. Cultivar L94 was used as a susceptible control it does not carry any minor and major genes to *P. hordei.* The plants were grown with 16h light and temperature range of 18-22°C. Urediniospores of *P. hordei* were suspended in deionized water with couple drops of mineral oil "Twin 20" and inoculated onto one week old seedling plants (primary leaf fully expanded) using a rate 3 mg urediniospores, 10 ml of water^{-1}, 100 plants $^{-1}$. Inoculated plants were incubated for 24 hours in a chamber in which the humidity was maintained near saturation by mist from ultrasonic humidifiers. Also, during this 24 hours, plants were kept in complete darkness and in temperature range of 12-15°C. Next plants were transferred to a greenhouse bench.

Disease assessment

Reactions of each accession were evaluated after an incubation period of 12-14 days in a greenhouse at 20-24°C range of temperature. Disease symptoms were assessed on the primary leaf of the seedlings according to 0-4 scale

adapted from Levine and Cherewick (1952) (Table 3). Infection types 0, 0;, 1 and 2 were considered indicative of host resistance and infection types 3 and 4 of host susceptibility.

Table 3

Description of infection types and codes used (adapted from Levine and Cherewick 1952).

Infection Type	Host Response	Symptoms
0	Immune	No vivible uredia
0;	Very resistant	Hypersensitive flecks
1	Resistant	Small uredia with necrosis
2	Moderately resistant	Small to medium sized uredia with green island,s surrounded by necrosis or chlorosis
3	Moderately suscept.	Medium sized uredia with or without chlorosis
4	Susceptible	Large uredia without chlorosis

Postulation of leaf-rust resistance genes

Accessions exhibiting the same reaction pattern as a specific differential line were postulated to carry the respective *Rph* gene. It was made on the basis of gene-for-gene hypothesis.

RESULTS

From 67 cultivars and breeding lines 41 (61%) showed resistance reaction after inoculation with at least one isolate of *P. hordei* (Table 4). In 29 cultivars and breeding lines (43.2%) it was postulate presence of specific resistance alleles. For most tested cultivars and breeding lines (56.8%) it was impossible to postulate the presence the specific resistance alleles. Twenty six (38.8%) cultivars and breeding lines showed susceptible reaction after inoculation with all isolates used. These cultivars have no resistance gene to *P. hordei* or they may have one or combination of three resistance genes (*Rph1*, *Rph10*, *Rph11*). Four cultivars and breeding lines (NAD 2298, Granal, Barke, BKH 4300) were composed of lines carrying different genes for resistance.

Four different resistance alleles (*Rph3*, *Rph7*, *Rph9* and *Rph12*) were detected alone or in combinations. Among tested cultivars and breeding lines, twenty had one gene for resistance and 8 had combination of different genes for resistance. The most common resistance allele was *Rph12* (19 cultivars and breeding lines). Alleles *Rph9* and *Rph3* were postulated in 4 cultivars and breeding lines. Allele *Rph7* was postulated to be present in only one cultivar Hanka. This allele determined resistance reaction type 0; for all isolates used.

Only 12.6% of infection types observed among tested cultivars and breeding lines were classified as leaf rust resistance (scores 0, 0;, 1 and 2) (Table 5). The most frequent infection type were 0 (5.6%) and 0; (5.0%). The most rare infection types observed were 1 (0.9%) and 2 (1.1%).

Table 4

Reaction of sixty seven cultivars and breeding lines of spring barley to infection by eight isolates of *Puccinia hordei*.

No.	Cultivar / breeding line	Isolates								Postulated resistance alleles	Possible alleles
		Ph-9	Ph-5	Ph-4	Ph-6	Ph-31	Ph-21	Ph-17	Ph-25		
1	2	3	4	5	6	7	8	9	10	11	12
1	Lot	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
2	Rudzik	4	4	4	4	4	1	4	4	*Pa9*	
3	Maresi	4	4	4	4	4	1	4	4	*Pa9*	
4	Edgar	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
5	Polo	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
6	Rodos	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
7	Rambo	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
8	Boss	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
9	Start	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
10	Bies	4	4	4	4	2	4	4	4	*?*	
11	Rabel	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
12	Rataj	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
13	Rodion	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
14	Atol	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
15	Brenda	4	4	0	4	4	0;	4	4	*Pa12, ?*	*[Pa4, Pa8, Pa3]*
16	Bryl	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
17	Orthega	4	4	4	4	4	2	4	4	*?*	
18	Rasbet	4	4	4	4	4	0;	4	4	*Pa12*	
19	Refren	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
20	Madonna	4	4	4	4	4	0;	4	4	*Pa12*	
21	Scarlett	1	0	0	4	4	0	4	4	*?*	

Table 4

continued

1	2	3	4	5	6	7	8	9	10	11	12
22	LP 2.2840	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
23	NAD 2298	4	4	4	4	4	0;+4	4	4	*Mix (Pa12, ?)*	
24	NAD 2398	1	0	0	4	4	0	4	4	*?*	
25	Gwarek	4	4	4	4	4	0;	4	4	*Pa12*	
26	Poldek	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
27	Rastik	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
28	Stratus	4	4	4	4	4	2	4	4	*?*	
29	Sezam	4	4	4	4	4	0;	4	4	*Pa12*	
30	Prosa	4	4	4	4	4	0	4	4	*?*	
31	Jersey	1	4	4	4	4	0	4	4	*?*	
32	LP 697.94	4	4	4	4	2	4	4	4	*?*	
33	NAD 2799	4	4	4	4	4	0;	4	4	*Pa12*	
34	NS 96 1114	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
35	P 7020	4	4	4	4	4	0;	4	4	*?*	
36	Pejas	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
37	STH 3499	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
38	Forum	0	2	0	4	4	0	4	4	*?*	
39	Orlik	4	4	4	4	4	1	4	4	*Pa9*	
40	Riviera	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
41	Blask /BKH 3798/	4	4	2	4	4	0;	4	4	*Pa12, ?*	
42	Granal /NAD 2498/	4	4	0;+4	4	4	0;	4	4	*Mix (Pa12, ?)*	
43	Justina /NS 96 1116	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
44	Annabell	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*

Table 4

continued

1	2	3	4	5	6	7	8	9	10	11	12
45	Antek /P 6616/	0	4	0	4	4	0	4	4	*Pa3*	
46	Barke	0+4	4	4	4	4	0	4	4	*Mix (?)*	
47	BKH 4200	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
48	BKH 4300	0+4	4	4	4	4	0;	4	4	*Mix (Pa12, ?)*	
49	BKH 4400	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
50	CSBA 4369-5	4	4	4	4	4	0;	4	4	*Pa12*	
51	GS 1848	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
52	GS 1850SEC 8311X	4	4	4	4	4	4	4	4	*?*	*[Pa1, Pa10, Pa11]*
53	Hadm 52559-95	4	4	4	4	4	0;	4	4	*Pa12*	
54	MOB 2000	4	4	4	4	4	0;	4	4	*Pa12*	
55	MOB 2100	4	4	4	4	4	0;	4	4	*Pa12*	
56	NAD 2800	4	4	0	4	4	0;	4	4	*Pa12, ?*	*[Pa4, Pa8, Pa3]*
57	NAD 2900	0	0	0	4	4	0	4	4	*Pa3, ?*	
58	NAD 3000	4	0	0	4	4	0	4	4	*?*	
59	POA 2400	0	0	0	4	4	0	4	4	*Pa3, ?*	
60	Prestige	0	4	0	4	4	0	4	4	*Pa3*	
61	Semu 51153-91 /Hanka/	0;	0;	0;	0;	0;	0;	0;	0;	*Pa7*	
62	STH 3600	4	4	4	4	4	0;	4	4	*Pa12*	
63	STH 3700	4	4	4	4	4	0;	4	4	*Pa12*	
64	STH 3800	4	4	4	4	4	0;	4	4	*Pa12*	
65	SW 1562	4	4	4	4	4	2	4	4	*?*	
66	Tolar	4	4	4	4	4	0;	4	4	*Pa12*	
67	Mobek	4	4	4	4	4	1	4	4	*Pa9*	

Table 5

Leaf rust infection types observed in tested cultivars and breeding lines

No	Cultivar / breeding line	Infection type					
		0	0;	1	2	3	4
1	2	3	4	5	6	7	8
1	Lot	0	0	0	0	0	8
2	Rudzik	0	0	0	0	0	8
3	Maresi	0	0	0	0	0	8
4	Edgar	0	0	0	0	0	8
5	Polo	0	0	0	0	0	8
6	Rodos	0	0	0	0	0	8
7	Rambo	0	0	0	0	0	8
8	Boss	0	0	0	0	0	8
9	Start	0	0	0	0	0	8
10	Bies	0	0	0	1	0	7
11	Rabel	0	0	0	0	0	8
12	Rataj	0	0	0	0	0	8
13	Rodion	0	0	0	0	0	8
14	Atol	0	0	0	0	0	8
15	Brenda	1	1	0	0	0	6
16	Bryl	0	0	0	0	0	8
17	Orthega	0	0	1	0	0	7
18	Rasbet	0	1	0	0	0	7
19	Refren	0	0	0	0	0	8
20	Madonna	0	1	0	0	0	7
21	Scarlett	3	0	1	0	0	4
22	LP 2.2840	0	0	0	0	0	8
23	NAD 2298	1*	0	0	0	0	8
24	NAD 2398	3	0	1	0	0	4
25	Gwarek	0	1	0	0	0	7
26	Poldek	0	0	0	0	0	8
27	Rastik	0	0	0	0	0	8
28	Stratus	0	0	0	1	0	7
29	Sezam	0	1	0	0	0	7
30	Prosa	1	0	0	0	0	7
31	Jersey	1	0	1	0	0	6
32	LP 697.94	0	0	0	1	0	7

Table 5

continued

1	2	3	4	5	6	7	8
33	NAD 2799	0	1	0	0	0	7
34	NS 96 1114	0	0	0	0	0	8
35	P 7020	0	1	0	0	0	7
36	Pejas	0	0	0	0	0	8
37	STH 3499	0	0	0	0	0	8
38	Forum	3	0	0	1	0	4
39	Orlik	1	0	0	0	0	7
40	Riviera	0	0	0	0	0	8
41	Blask /BKH 3798/	0	1	0	1	0	6
42	Granal /NAD 2498/	0	2*	0	0	0	7
43	Justina /NS 96 1116	0	0	0	0	0	8
44	Annabell	0	0	0	0	0	8
45	Antek /P 6616/	3	0	0	0	0	5
46	Barke	2*	0	0	0	0	7
47	BKH 4200	0	0	0	0	0	8
48	BKH 4300	1*	1	0	0	0	7
49	BKH 4400	0	0	0	0	0	8
50	CSBA 4369-5	0	1	0	0	0	7
51	GS 1848	0	0	0	0	0	8
52	GS 1850SEC 8311X	0	0	0	0	0	8
53	Hadm 52559-95	0	1	0	0	0	7
54	MOB 2000	0	1	0	0	0	7
55	MOB 2100	0	1	0	0	0	7
56	NAD 2800	1	1	0	0	0	6
57	NAD 2900	4	0	0	0	0	4
58	NAD 3000	3	0	0	0	0	5
59	POA 2400	4	0	0	0	0	4
60	Prestige	3	0	0	0	0	5
61	Semu 51153-91 /Hanka/	0	8	0	0	0	0
62	STH 3600	0	1	0	0	0	7
63	STH 3700	0	1	0	0	0	7
64	STH 3800	0	1	0	0	0	7
65	SW 1562	0	0	0	1	0	7
66	Tolar	0	1	0	0	0	7
67	Mobek	0	0	1	0	0	7
	%	5.6	5.0	0.9	1.1	0	87.4

DISCUSSION

In many countries of Europe, farmers apply repeated fungicide treatments on barley to protect against fungal leaf pathogens, including *P. hordei*. However, there is increasing opposition to the application of large amounts of pesticides in agriculture, because of environmental and health risks (Czembor 2005, Nieróbca *et al.* 2003). The obvious alternative to fungicide treatment against plant diseases is the use of resistant cultivars (Alemayehu 1995, Cotterill *et al.* 1995, Czembor 2005, Czembor and Gacek 1990). The obtained results indicated lack of resistance or very low resistance to *P. hordei* in barley cultivars and breeding lines. Taking this into account, it is recommended to use fungicides to control barley leaf rust and to use various strategies for resistance gene deployment (Czembor 1996, 2005, Finckh *et al.* 2000). In addition there is need to identify and use new sources of resistance to this pathogen in barley breeding programmes (Alemayehu and Parlevliet 1996, Backes *et al.* 2003, Jin *et al.* 1995, Manisterski and Anikster 1995).

Barley leaf rust is characterised by large genetic variability (Brodny and Rivadeneira 1996, Fetch *et al.* 1998, Park 2003). Interesting fact is that races of *P. hordei* in Europe, North Africa and the Middle East have virulences to genes that have not been widely deployed in these regions (Parlevliet 1976, 1983a, b, Reinhold and Sharp 1982). Use of specific resistance genes in barley quickly results in selection of virulent races of *P. hordei*. Good exaple for this situation is deployment in barley cultivars of rene *Rph7* from Cebada Capa. This gene was the most effective leaf rust resistance genes in barley and cultivars with this gene were widely grown in the southeastern US beginning in the late 1960s. It remained effective until the early 1990s, when virulence was detected in collections from the southeast of US and California (Steffenson *et al.* 1993). Although virulence to *Rph7* occurred previously in Israel and North Africa, the origin of this virulence in the US was considered most likely to be due to mutation and selection (Alemayehu 1995, Niks *et al.* 2000, Steffenson *et al.* 1993).

Until about 1970, most leaf rust resistance breeding programs utilized specific *Rph* genes as sources of resistance, but few of the genes have been widely used commercially (Alemayehu 1995, Niks *et al.* 2000). The resistance genes that were used usually occured singly in released cultivars. Because of this fact, the resistance conferred by these genes was not durable (Lindhout 2002). Parlevliet (1983a) concluded that, excepted for *Rph7*, individual *Rph* genes were not worth deploying commercially. Interest in more durable resistance to leaf rust began in Europe about 1970 by the observation of "non-hypersensitive" resistance, and its further evaluation as "slow rusting" (Alemayehu 1995, Niks *et al.* 2000). Parlevliet (1983a, b) concluded that in 70ties of last century most European barley cultivars carried no *Rph* genes, but "partial" resistance was widespread, readily available and relatively easy to transfer. During this time the "partial" resistance to leaf rust in barley was effective, and has shown little evidence of serious erosion, despite an observed increases in fitness of

leaf rust populations to cultivar Vada (Alemayehu 1995, Niks *et al.* 2000, Parlevliet 1983a, b). However in recent years it is observed in Central Europe that leaf rust is causing more and more yield losses in most commonly grown cultivars. Most probably it is caused by "dilution" or lost of partial resistance to this pathogen in the breeding process (Niks personal communication). Because of this fact it is recommended to conduct greenhouse tests of breeding material for leaf rust resistance.

Among 16 described resistance genes for leaf rust only genes *Rph 7* and *Rph 16* are effective against European population of leaf rust. In past the most commonly used genes in barley breeding were *Rph3*, *Rph9* and *Rph12* (Brooks et. al 2000, Walther 1996). This was confirmed in our study because the most common resistance allele in tested cultivars and breeding lines was *Rph12* (19 cultivars and breeding lines) and alleles *Rph9* and *Rph3* were postulated in 4 cultivars and breeding lines.

Described studies were carried out on seedlings. However, partial resistance is generally better expressed in the adult plant stage (Parlevliet and van Ommeren 1975, Smit and Parlevliet 1990). Based on this it will be interesting to extend presented studies to adult plants as well. In addition, further studies are needed to determine the number of genes, the types of gene, the type of gene action and the gene loci in resistant lines. It may be established only by crosses and backcrosses among appropriate genotypes (Alemayehu 1995, Jin and Steffenson 1994, Martinez *et al.* 2001).

Described investigation resulted in information about resistance alleles for leaf rust present in cultivars and breeding lines used in agriculture. This kind of information will help breeders to use proper breeding initial material and to use the most effective breeding techniques in breeding barley resistant to this pathogen (Czembor 2005, Czembor and Gacek 1990, Finckh *et al.* 2000, Vallavieille-Pope *et al.* 2000). Presented information is also very valuable in order to proper interpret interactions between populations of the *P. hordei* and barley and to recommend the most effective method for deployment of available resistance genes in grown cultivars.

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