Identification of Genes for Resistance to Wheat Powdery Mildew in Hungarian, Polish and Slovak Wheat Cultivars

MIROSLAV ŠVEC[1], LÁSZLÓ SZUNICS[2], MARTA MIKLOVIČOVÁ[1], TATIANA SLOVÁKOVÁ[3], VIERA TISOVÁ[4] and PAVOL HAUPTVOGEL[4]

[1]Department of Genetics, Comenius University, Bratislava, Slovak Republic; [2]Agricultural Research Institute, Martonvásár, Hungary; [3]Department of Plant Physiology, Comenius University, Bratislava, Slovak Republic; [4]Research Institute of Plant Production, Piešťany, Slovak Republic

Abstract

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The objective of the study was to identify genes for resistance to powdery mildew in wheat cultivars and land races from Poland, Slovakia and Hungary. The presence and distribution of resistance genes was compared to powdery mildew virulence structure in these countries. The different strategies in breeding for resistance were expressed in a different distribution of resistance genes, especially among Polish and Hungarian cultivars. In 20 of the 29 Hungarian common wheat cultivars the resistance gene *Pm8* was found. Of the 32 Polish cultivars investigated, 16 possess a combination of genes *Pm2+6*. Resistance gene *Pm4b* did not occur in any Hungarian cultivar tested, and resistance gene *pm5* was not detected in any Polish cultivar. Virulence in wheat powdery mildew populations was influenced by differences in distribution of resistance genes in host genotypes. The most significant difference was found between Polish and Hungarian powdery mildew populations. The two populations differed mainly in virulence against *Pm2*. Resistance gene *MlAr* was detected in three old Slovak cultivars.

Keywords: wheat; *Triticum aestivum*; powdery mildew; *Blumeria graminis* DC f.sp. *tritici*; resistance genes; virulence analysis

Powdery mildew resistance genes can be identified either by an approximative method based on a differential set of powdery mildew isolates, or by RFLP markers closely linked to the particular resistance genes. Specific resistance genes were for the first time identified through the analysis of host-pathogen interactions in German wheat cultivars (HEUN & FISCHBECK 1987). Many resistance genes incorporated in wheat cultivars from different countries have been identified this way (HØVMOLLER 1989; LUTZ *et al.* 1992; ZELLER *et al.* 1993b; LIMPERT *et al.* 1994; PADERINA *et al.* 1995; PEUSHA *et al.* 1996; HUANG *et al.* 1997a). So far, 28 resistance genes designated as *Pm1–Pm28* have already been identified and localized (HUANG *et al.* 1997b; MCINTOSH *et al.* 1998; PEUSHA *et al.* 2000). Except for the identified resistance genes there still exists a group of genes that have not been localized yet. Such a gene is marked by both symbol *Ml* and an abbreviation of the cultivar in which it was found first (BOESEN *et al.* 1996). It is very advantageous to use RFLP markers to identify resistance genes because additional resistance genes can simultaneously be identified in one genotype, especially if it possesses total resistance. Molecular markers for resistance genes *Pm1*, *Pm2* and *Pm9* (SCHNEIDER *et al*. 1991; MA *et al.* 1994) as well as markers distinguishing between alleles of the *Pm3* locus (HARTL *et al.* 1993) have already been found. Markers found for the *Pm4* locus (MA *et al*. 1994) do not distinguish between alleles *Pm4a* and *Pm4b*. The identification of specific resistance genes is very important because it helps breeders to choose the right donor of resistance. It also contributes to a more detailed characterisation of wheat cultivars.

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Our objective was to study the distribution of specific resistance genes in wheat cultivars from Poland, Slovakia and Hungary and to compare it to virulence frequencies in powdery mildew populations monitored in these three countries. For Slovakia we concentrated on old cultivars and land races because genes conferring resistance against powdery mildew in the present assortment of Slovak cultivars and those recently excluded from registration have already been determined (LUTZ *et al.* 1992; ŠVEC *et al.* 1999). Information about resistance genes present in some Polish wheat cultivars has been published by KOWALCZYK *et al.* (1998).

MATERIALS AND METHODS

Samples of the registered Polish wheat cultivars were obtained from the Gene Bank in Radzikow. Hungarian wheat cultivars were provided by the Agricultural Research Institute of the Hungarian Academy of Sciences in Martonvásár. Old Slovak cultivars together with land races were obtained from the Gene Bank in Piešťany. The differential set of wheat cultivars carrying different resistance genes was kindly provided by Dr. M. Winzeler from the Swiss Federal Research Station for Agronomy in Zürich-Reckenholz. A set of 15 powdery mildew (*Bgt*) differential isolates (Table 1) chosen from almost 3000 isolates collected in Slovakia and its neighbouring countries in 1993–1998 was used to analyse the resistance of a host. Each of these isolates was obtained from single colony progenies. Tests were carried out on 20 mm segments of host primary leaves, with two leaf segments from each wheat genotype. The segments were placed in a Petri dish on 6 g/l agar containing 35 mg/l benzimidazole. The tests were repeated four times.

The method of inoculation and assessment of the reaction were carried out according to LUTZ *et al.* (1992). Three types of host reactions were distinguished: r – resistant, i – intermediate, s – susceptible.

Random spore samples of powdery mildew of wheat were acquired from Hungary, Poland and Slovakia by a jet spore sampler mounted on the roof of a car. For more detailed information about virulence analysis methods see LIMPERT *et al.* (1987) and ŠVEC *et al.* (1998).

RESULTS

The set of 15 *Bgt* isolates was used to determine the resistance genes in the wheat cultivars.

The reactions of 27 Hungarian common wheats and two durum wheats are given in Table 2. In comparison with the response of cultivars carrying known resistance genes it becomes evident that cvs Mv24, Irma, Emma, Magvas, Mezoföld and Martondur 2 appear to contain no known major resistance genes as they were susceptible to all isolates. Other cultivars tested carry at least gene *Pm8*, except for Martondur1 in which the set of isolates

Table1. Reactions of 16 wheat cultivars possessing known powdery mildew resistance genes or alleles after inoculation with 15 differential isolates of *Blumeria graminis* f.sp. *tritici* (r = resistant, i = intermediate, s = susceptible reaction)

Cultivar	Resistance gene	I 1	I 2	I 3	I 4	I 5	I 6	I 7	I 8	I 9	I10	I11	I12	I13	I14	I15
Axminster/8CC[a]	*Pm1*	r	s	s	s	s	s	s	s	s	s	r	s	s	r	s
M.Huntsman	*Pm2+6*	r	s	r	s	s	s	s	s	r, i	s	s	s	s	s	r
Asosan/CC	*Pm3a*	s	s	s	s	r	s	r	r	r	s	s	r	r	r	s
Chul/CC	*Pm3b*	r	r	s	r	r	r	r	s	r	r	r	r	r	r	r
Sonora/CC	*Pm3c*	s	s	s	s	s	s	r	s	s	s	s	s	s	s	s
Kolibri	*Pm3d*	s	r	r	r	r	r	r	r	s	s	s	r	r	s	s
W150	*Pm3e*	s	s	s	s	s	i	r	r	s	s	s	r	i	s	s
Michigan Amber	*Pm3f*	s	s	s	s	s	s	r	r	s	s	s	s	s	s	s
Khapli/CC	*Pm4a*	s	s	s	r	s	r	s	s	r	r	s	s	s	s	s
Armada	*Pm4b*	s	s	s	r	r	r	s	s	r	r	s	s	s	s	s
Regina	*pm5*	s	s	s	s	s	s	s	s	s	s	s	*r*	*r*	*s*	*s*
*T*imgalen	*Pm6*	s	s	s	s	s	s	s	s	r, i	s	s	s	s	s	s
Salzmuende 44	*Pm8*	s	r	s	s	s	r, i	r	s	s	r	s	s	s	s	s
Maris Dove	*Mld*	r	r	r	r	s	i	r	i	r	r	s	r	r	s	r
Normandie	*Pm1+2+9*	r	s	r	s	s	s	s	s	r	s	r	s	s	r	s
Amigo	*Pm17*	r	r	r	r	r	i	r	r	r	r	i	i	r	r	s

[a] eight times backcrossed to cv. Chancellor

Table 2. Reactions of 29 Hungarian wheat cultivars after inoculation with 15 differential isolates of *Blumeria graminis* f.sp. *tritici* (r = resistant, i = intermediate, s = susceptible, x = segregating plants)

Cultivar	Postulated resistance gene/s	I 1	I 2	I 3	I 4	I 5	I 6	I 7	I 8	I 9	I10	I11	I12	I13	I14	I15
Mv15	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Mv16	*Pm5+8*	s	r	s	s	s	r	r	s	s	r	s	r	r	s	s
Mv17	*Pm2+6+8*	r	r	r	s	s	r	r	s	i	r	s	s	s	s	r
Mv19	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Mv20	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Mv21	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Mv22	*Pm2+5+8*	r	r	r	s	s	i	r	s	i	r	s	r	r	s	r
Mv23	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Mv24	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Mv25	*pm5+8*	s	r	s	s	s	r	r	s	s	r	s	r	r	s	s
Koma	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Pálma	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Madrigál	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Summa	*Pm2+6+8x*	r	r, s	r	s	s	i	r	s	i	r, s	s	s	s	s	r
Fatima-2	*pm5+8*	s	r	s	s	s	r	r	s	s	r	s	r	r	s	s
Optima	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Vilma	*Pm8*	s	r	s	s	s	i	r	s	s	r	s	s	s	s	s
Szigma	*Pm8x*	s	r,s	s	s	s	i	r, s	s	s	r, s	s	s	s	s	s
Magdaléna	*Pm8x*	s	r,s	s	s	s	r	r, s	s	s	r, s	s	s	s	s	s
Matador	*Pm8x*	s	r,s	s	s	s	r, s	r, s	s	s	r, s	s	s	s	s	s
Tamara	*Pm8x*	s	r,s	s	s	s	r	r, s	s	s	r, s	s	s	s	s	s
Martina	*Pm8x*	s	r	s	s	s	r	r, s	s	s	r	s	s	s	s	s
Kucsma	*Pm8x*	s	r,s	s	s	s	r, s	r, s	s	s	r, s	s	s	s	s	s
Irma	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Emma	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Magvas	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Mezoföld	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Martondur 1	unknown	s	s	r, s	r	i	s	s	s	r	s	s	s	s	s	r
Martondur 2	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s

did not identify any known resistance gene. Gene *Pm8* is present either alone in 15 cultivars (Mv15, Mv19, Mv21, Mv23, Koma, Pálma, Madrigál, Optima, Vilma, Szigma, Magdaléna, Matador, Tamara, Martina and Kucsma) or combined with *pm5* and *Pm2*. Cultivars Mv16, Mv22, Mv25 and Fatima-2 are characterized by the gene combination *pm5+Pm8*. In cultivars Mv17, Mv22 and Summa, gene *Pm8* is combined with *Pm2*.

Of the 32 Polish cultivars investigated, 12 did not carry any specific resistance gene (Table 3). Half of the cultivars (16) carry the gene combination *Pm2+6* in their genotypes. Gene *Pm8* is combined with genes *Pm2+6* in cv. Izolda. Cultivar Wilga carries gene *Pm4b*. Some cultivars showed patterns of reaction that could not be attributed to any known resistance genes. The cv. Kobra appears to carry the gene combination *Pm2+6* and some unknown resistance gene because the cultivar showed a resistant reaction to isolates I2 and I8. The cvs Korweta, Lama and Muza showed various resistant reactions but we were not able to identify any resistance gene in them. Gene *pm5* did not occur in any Polish cultivar.

Fifteen Slovak cultivars and land races were characteristic for their low number of resistant reactions. Only the three cvs Slovenská 2, Šamorínska and Vígľašská červ. were resistant to powdery mildew isolate I8 which is the only isolate avirulent to gene *MlAr* (Table 4).

To determine the selection pressure caused by the resistance genes incorporated in cultivars registered in the

Table 3. Reactions of 32 Polish wheat cultivars after inoculation with 15 differential isolates of *Blumeria graminis* f.sp. *tritici* (r = resistant, i = intermediate, s = susceptible, x = segregating plants)

Cultivar	Supposed resistance gene/s	I 1	I 2	I 3	I 4	I 5	I 6	I 7	I 8	I 9	I10	I11	I12	I13	I14	I15
Alba	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Aleta	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Almari	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Arda	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Begra	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Emika	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Gama	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Izolda	*Pm2+6+8*	r	r	r	s	s	i	r, s	s	r	r	s	s	s	s	r
Jawa	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Jubilatka	*Pm2+6*	r	s	r, s	s	s	s	s	s	r	s	s	s	s	s	r
Juma	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Kamila	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Kobra	*Pm2+6+u*	r	r, s	r	s	s	s	s	r	r	s	s	s	s	s	r
Korweta	u?	r	s	s	s	s	s	s	r, s	s	s	s	s	s	s	s
Lama	u?	s	s	s	s	s	r	s	r	s	s	s	s	s	s	s
Maltanka	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Muza	u?	r	s	s	s	s	r, s	s	r, s	s	s	s	s	s	s	r, s
Oda	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Olcha	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Olma	*Pm2+6x*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r, s
Panda	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Parada	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Roma	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Rosa	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Sakwa	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Sielanka	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Soraja	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Sukces	none	s	s	s	s	s	s	s	s	s	s	s	*s*	*s*	*s*	*s*
Tercja	*Pm2+6+8*	r	r	r	i, s	s	i	i, s	s	r	r	s	s	s	s	r
Wilga	*Pm4b+8*	s	r	s	r	r	r	r, s	s	r	r	s	s	s	s	s
Zorza	*Pm2+6*	r	s	r	s	s	s	s	s	r	s	s	s	s	s	r
Zyta	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s

particular country, the virulence frequencies against the resistance genes can be used. These virulence frequencies are given in Table 5. Genes *pm5, Pm6, Pm8* and *MlAr* were identified in the cultivars investigated, but they are ineffective in Hungary, Poland and Slovakia as virulence against these genes was 100% or close to it. Virulence against *Pm4b* reached the same value in Poland and Hungary. Powdery mildew populations obtained from Poland and Hungary differed in virulence against *Pm2*; it was more frequent in Poland than in Hungary.

DISCUSSION

A set of differential isolates of *Blumeria graminis* f.sp. *tritici* was used to determine the known powdery mildew resistance genes in host cultivars. From the results presented in Table 2 it is obvious that *Pm8* is the most frequent gene in Hungarian wheat cultivars. By comparing the pedigrees of the cultivars with resistance genes it becomes evident that *Pm8* was introduced to cvs Mv15, Mv16 and Mv20 from cv. Kavkaz by T1BL.1RS translo-

Table 4. Reactions of 15 old Slovak wheats after inoculation with 15 differential isolates of *Blumeria graminis* f.sp. *tritici* (r = resistant, s = susceptible)

Cultivar	Postulated resistance gene/s	I 1	I 2	I 3	I 4	I 5	I 6	I 7	I 8	I 9	I10	I11	I12	I13	I14	I15
Bučianska 106	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Bučianska 316	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Bučianska červ.	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Slovenská B	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Slovenská 2	*MlAr*	s	s	s	s	s	s	s	r	s	s	s	s	s	s	s
Slovenská 777	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Slovenská 1784	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Radošínska Raná	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Radošínska	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Košútska	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Vígľašská červ.	*MlAr*	s	s	s	s	s	s	s	r	s	s	s	s	s	s	s
Vrakunská	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Šamorínska	*MlAr*	s	s	s	s	s	s	s	r	s	s	s	s	s	s	s
Čalovská	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s
Nový život	none	s	s	s	s	s	s	s	s	s	s	s	s	s	s	s

Table 5. Frequency of powdery mildew virulence against some specific resistance genes in 1997 (in %)

Country	Resistance genes													
	Pm1	*Pm2*	*Pm3a*	*Pm3b*	*Pm3c*	*Pm4a*	*Pm4b*	*pm5*	*Pm6*	*Pm8*	*Pm9*	*Mli*	*Mld*	*MlAr*
Hungary	51	65	28	19	85	68	46	99	97	99	23	99	11	100
Slovakia	61	66	45	17	81	70	38	97	98	99	26	99	22	100
Poland	59	74	45	21	80	59	46	99	92	96	36	100	34	100

Number of tested isolates: Hungary = 157; Slovakia = 172; Poland = 78

cation (Table 6). Gene *Pm8* in cv. Mv25 may have been derived from Fundulea 29, since cv. Avrora, one of the sources of the T1BL.1RS translocation, is one of its parents, or from cv. Bezostaya 2. Gene *Pm8* in cvs Mv17 and Mv23 may have been inherited from cultivar Mv Tf (Martonvásár dwarf) which has Bezostaya 2 and Kavkaz in its pedigree. The origin of *Pm8* in cvs Mv21 and Mv22 could be attributed to cv. NS 2568-2 which has *Pm8* from Skorospelka 35, and in Mv19 to GT 5239-2 which carries the translocation from Avrora (BEDÖ *et al.* 1993). Also, according to LIMPERT *et al.*(1994), cvs Baranjka (ZG 4431) or Mv Tf appear to carry genes *Pm2* and *Pm8*. One of these two genotypes is part of the pedigree of cvs Mv17, Mv19, Mv21, Mv22 and Mv23. The cvs Mv24 and Irma did not show a reaction pattern typical for the presence of gene *Pm8* even though a short rye chromosome arm was detected in Mv24 (MOLNÁR-LÁNG *et al.* 2000). This may be due to the influence of dominant suppressor gene *SuPm8* (HANUŠOVÁ *et al.* 1996).

After inoculation with isolates avirulent to *Pm8*, several Chinese cultivars carrying translocated chromosome 1BL.1RS gave a susceptible reaction (HUANG *et al.* 1997a). The presence of gene *Pm8* was not proved in all plants of the cvs Summa, Szigma, Magdaléna, Matador, Tamara, Martina and Kucsma. The reason of this may be the heterozygosity of variety or the influence of suppression. Gene *Pm8* in the latest registered cvs Palma, Madrigál and Vilma can be derived from older Martonvásár cultivars (Mv 15, Mv 16). Gene *pm5* of cv. Mv16 can be traced to cv. Arthur possessing gene combination *pm5* and *Pm6* (LEATH & HEUN 1990). The putative donor of *pm5* in cv. Mv25 seems to be cv. Fundulea 29 since cv. Red Coat carrying gene *pm5* is one of its parents (WOLFE 1967). The source of resistance gene *Pm2* in cvs Mv17

Table 6. Genealogies of 25 Hungarian wheat cultivars

Variety	Pedigree
Martonvásár Mv15	Kavkaz/Mironovskaya 808/Kavkaz/Zlatna Dolina
Martonvásár Mv16	Mv 4/Kavkaz/P4089/3/Zlatna Dolina/Arthur/Rubin
Martonvásár Mv17	Slavia/Mv Tf/ZG 4431(Baranjka)
Martonvásár Mv19	GT 5239-2//Krasnodar 1/ZG 1477
Martonvásár Mv20	Kavkaz/Mironovskaya 808/Kavkaz/Zlatna Dolina
Martonvásár Mv21	SO 1415/Ilyichevka/NS 2568-2
Martonvásár Mv22	NS 2568-2//KR-1/ZG 1477-69/3/ZG 4431(Baranjka)
Martonvásár Mv23	GT 13 A354/Mv Tf//Mv 5/3/, GK Tiszatáj
Martonvásár Mv24	GT13A 305//Krasnodar1/ZG 1477-69/3/Krasnodar 1/ZG 1447-69/Kavkaz
Martonvásár Mv25	Fundulea 29/3/Mv 3/SKC 1055//Bezostaya 2/Krasnodar 1
Koma	GT13A/Mv 5//Baranjka/3/GK Tiszatáj
Pálma	F797/Mv 08-82//Mv 15
Madrigál	Mv 16-85/Viginta
Summa	GK 36-83/SO 1586//Mv 17
Fatima-2	Fundulea 29/Lovrin 32
Optima	762-10-1-2-3/4/Mv 9
Vilma	F 797/Mv 08-82//Mv 15
Szigma	Mv 21-85/Mv 15
Irma	T16/Mv 5//SO 6300/3/Novosadska Rana 2/Mv 15//SO 6300
Emma	Mv 15/Mv 8//Mv MA
Magdaléna	Jubileyna 50/Fundulea 29// Mv MA
Magvas	F 26-70/Mv K2//Mv MA
Mezoföld	GK Othalom/Mv 15
Martondur 1	DF 205-82/Korall
Martondur 2	GK Minaret/Dagestan line//Krystall 2/3/Korall/4/DF 623

and Mv22 is unknown. The pedigree available for cv. Mv20 indicates that it may only contain gene *Pm8* from cv. Kavkaz since Mironovskaya 808 (LUTZ *et al*. 1992) as well as cv. Zlatna Dolina do not possess any major resistance gene. From the results on the Hungarian wheat cultivars it can be clearly assumed that genotypes possessing *Pm8* were predominantly used as genetic resources to create new cultivars.

The situation is different in Polish wheat cultivars. The gene combination *Pm2+6* was the most frequent one. This combination originated from cv. Maris Huntsman, which can be found in the pedigrees of cvs Oda, Juma, Alba, Lama, Jubilatka, Almari, Sakwa, Kobra, Tercja, Arda, Olma, Parada, Roma, Maltanka, Soraja and Muza (Table 7). Gene combination *Pm2+6* was identified in 11 of these cultivars. The source of resistance genes *Pm2* and *Pm6* in cvs Izolda, Kamila and Sielanka is unknown. Genes *Pm2* and *Pm6* in cv. Olcha seem to be derived from cv. Maris Fundin. Gene *Pm2* was identified by KOWALCZYK *et al.* (1998) in 12 cultivars of the set of cultivars in which we detected *Pm2*. Moreover, *Pm2* was also detected in cvs Korweta, Lama, Oda and Roma by those authors. Its presence in the last three cultivars is highly probable as they have cv. Maris Huntsman in their pedigree (Table 7). The differences in results may have been caused by the use of different accessions of the four cultivars.

We identified gene *Pm4b* in one cultivar. Cultivar Wilga has probably inherited this gene and *Pm8* from cv. Juwel (HEUN & FISCHBECK 1987). Two cultivars contained gene *Pm8* in their genotypes. Three Polish cultivars showed a response pattern that does not agree with that of any known resistance gene. However, the existence of several resistant reactions reveals the presence of some unknown resistance gene in these cultivars. It is unusual for a resistance gene to be present in almost 50% of registered cultivars. HUANG *et al*. (1997a) detected *Pm8* in one third of the 50 genotypes grown in China. The frequency of *Pm6* in cultivars of Western Siberia was 33% (PADERINA *et al*. 1995). Among 35 French

Table 7. Genealogies of 32 Polish wheat cultivars and 3 lines

Variety	Pedigree
Alba	MarisHuntsman/L832$_{70}$///Welgue/Dankowska Biala//Luna// Grana
Almari	Maris Huntsman/Alcedo
Arda	Maris Huntsman/C 171-73
Begra	Grana/Bezostaya 1
Emika	Etoile de Choisy/Mironovskaya 808//Perdix
Gama	Mironovskaya 808/Luna
Izolda	TAW 13763-76/P 3567-73
Jawa	Eureca/Grana//Cebeco 72/Sylvia
Jubilatka	Maris Huntsman/Niwa//Orla/Niwa///DED 739-75
Juma	Maris Huntsman/Mironovskaya Jubileyna// Maris Huntsman
Kamila	Kranich/WW 153//Beta
Kobra	Maris Huntsman/Krasnodar 39//Mironovskaya 808/Luna
Korweta	C 3672-77/Gama
Lama	Maris Huntsman/Jana//C 474-73
Maltanka	Kavkaz/Grana// Maris Huntsman
Muza	SMH 481/Kristal 7//SMH 1320
Oda	S 318-72/Maris Huntsman
Olcha	Maris Fundin/Ekstrem
Olma	Kavkaz/Grana// Maris Huntsman
Panda	Dana/Flavina
Parada	Maris Huntsman//N 5736/Mironovskaya 808
Rosa	Nadjeznaya 15//Grana/Luna
Roma	AR 112-74/ Maris Huntsman//Niwa/ Maris Huntsman
Sakwa	STH 132/UH 318//STH 1527
Sielanka	Grana/Remois
Soraja	STH 1623/Almari
Sukces	Jubilatka/SMH 2182
Tercja	Emika/ Maris Huntsman
Wilga	Juwell/Lanca
Zorza	TAW 13763-76/ P 3567-73
Zyta	Jubilatka/SMH 2182
Aleta	? (not found)
STH 1262	Jubileyna 50/Maris Huntsman//Hohenthurn 8174/Grana///Maris Huntsman
SMH 1320	Maris Huntsman//NS 736/Mironovskaya 808
SMH 1623	Alcedo/Sava//Maris Huntsman///Mironovskaya 10

cultivars investigated, 17% contained gene *Pm2* (ZELLER *et al*. 1993b).

The fact that only gene *MlAr* was determined in the old Slovak cultivars indicates that no attention was paid to breeding for resistance in Slovakia in the past. Gene *MlAr* is also present in three French cultivars (ZELLER *et al*. 1993a), two Norwegian and two Siberian cultivars (PADERINA *et al.* 1995). However, *MlAr* is not effective any more since virulence against this gene reaches 100% in Slovakia and its neighbouring countries. Even the majority of currently used Slovak cultivars do not carry any major resistance gene. Two Slovak cultivars are characterized by gene combination *Pm2+6*, and only one cultivar possesses gene *Pm4b* (LUTZ *et al*. 1992; ŠVEC *et al*. 1999).

Comparing the results from Poland and Hungary makes obvious that different genetic resources were used in breeding for resistance in these two countries. While breeders from Hungary concentrated on genetic resources carrying *Pm8* in their genotypes, breeders from Poland were using especially sources with genes *Pm2* and *Pm6*. It is interesting that we did not identify *pm5* in Polish cultivars, nor *Pm4b* in Hungarian cultivars. The spectrum of resistance genes in host cultivars also influenced the structure of powdery mildew populations in Poland and Hungary. There were striking differences in the virulence frequency against *Pm2*. Although gene *Pm4b* is absent in Hungarian cultivars, we found out that virulence against *Pm4b* was equally frequent in both countries. This may have been caused by a migration of pathotypes from neighbouring Austria, where virulence against *Pm4b* lies in the range of 80-100% (MIKLOVIČOVÁ – unpublished).

Only a limited number of resistance genes is present in Polish, Slovak and Hungarian wheat cultivars. These genes are used in all European countries and they reduce powdery mildew to a low or intermediate level of attack. Nevertheless, it is necessary to introduce new resistance genes to new cultivars to maintain a reliable protection against the pathogen.

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Súhrn

ŠVEC M., SZUNICS L., MIKLOVIČOVÁ M., SLOVÁKOVÁ T., TISOVÁ V., HAUPTVOGEL P. (2002): I**dentifikácia génov rezistencie voči múčnatke trávovej v odrodách maďarských, poľských a slovenských pšeníc**. Plant Protect. Sci., **38**: 64–72.

Cieľom tejto práce bolo identifikovať gény rezistencie voči múčnatke trávovej v odrodách pšeníc z Maďarska, Poľska a Slovenska, pričom zastúpenie génov rezistencie v sortimente pšeníc sme porovnávali so štruktúrou virulencie v jednotlivých krajinách. Zaznamenali sme využitie rôznych stratégií v šľachtení na rezistenciu, a to najmä v porovnaní maďarských a poľských pšeníc. Spomedzi 29 analyzovaných maďarských odrôd pšeníc 22 obsahovalo gén rezistencie *Pm8*. Pri 16 poľských odrodách z tridsať dva testovaných sme zistili prítomnosť génovej kombinácie *Pm2+6*. Gén *Pm4b* sa nevyskytoval v žiadnej maďarskej odrode a ani u jednej poľskej odrody nebol identifikovaný gén rezistencie *pm5*. Odlišným zastúpením génov rezistencie bola ovplyvnená aj štruktúra populácií múčnatky trávovej. Najvýraznejšie rozdiely sme zistili medzi poľskými a maďarskými populáciami múčnatky, ktoré sa odlišovali najmä vo virulencii voči *Pm2*. U troch krajových odrôd zo Slovenska sme identifikovali gén rezistencie *MlAr*.

Kľúčové slová: pšenica; odrody pšenice; múčnatka trávová; gény rezistencie; virulenčná analýza

Corresponding author:

RNDr. MIROSLAV ŠVEC, Univerzita J. A. Komenského, Prírodovedecká fakulta, Katedra genetiky, Mlynská dolina B-1, 842 15 Bratislava, Slovenská republika
tel.: + 421 2 60 29 64 34, fax: + 421 2 65 42 90 64, e-mail: msvec@fns.uniba.sk