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Identification of powdery mildew resistance genes in common wheat (*Triticum aestivum* L. em. Thell.). XI. Cultivars grown in Poland

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Abstract. A collection of common wheat cultivars grown in Poland were analyzed for resistance to powdery mildew disease by using eleven differential isolates of *Erysiphe graminis* f. sp. *tritici* (*Blumeria graminis*). Among a total of 69 accessions, 48 cultivars possessed resistance which is attributed to known resistance genes present either individually or in a combination. Four cultivars were resistant to all the isolates used and another four cultivars revealed race-specific resistance which does not correspond to the response patterns of previously documented resistance. Resistance genes *Pm2* and *Pm6* in a combination were most widely distributed, and genes *Pm3d*, *Pm4b*, *Pm5* and *Pm8* were also postulated.

Key words: *Erysiphe graminis* (*Blumeria graminis*), pathogen isolates, resistance genes, *Triticum aestivum*.

Introduction

Common wheat (*Triticum aestivum* L.) is the most important crop in Polish agriculture. The main objectives of wheat breeding in Poland enclude improvement of yield, protein quality and protein content as well as resistance to diseases (MIAZGA, KOWALCZYK 1991). Powdery mildew, caused by *Erysiphe graminis* f. sp. *tritici*, is one of the most destructive foliar diseases of common wheat in Poland (STRZEMBICKA, ŁAZARSKA, (1996). The most effective approach to control this disease is the use of resistance genes. In Central European

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countries, nine resistance gene loci to powdery mildew are being utilized in commercial wheat cultivars, namely *Pm1*, *Pm2*, *Pm3c*, *Pm3d*, *Pm4b*, *Pm5*, *Pm6*, *Pm8* and *Pm9* (ZELLER et al. 1993b). The present study was undertaken to screen common wheat cultivars grown in Poland for resistance genes to powdery mildew.

Material and methods

The near-isogenic lines of Chancellor with known powdery mildew resistance genes, TP114/2* Starke having gene *Pm6* and the Chinese landrace Chiyacao carrying gene *Pm24* (HUANG et al. 1997), were kindly provided by R.A. McIntosh, Camden, Australia and X.F. Wang, Zhengzhou, China, respectively. The wheat cultivars and breeding lines grown in Poland come from the wheat collection of the Institute of Genetics and Plant Breeding, Lublin, from the Gene Bank at the Plant Breeding and Acclimatization Institute, Radzików, Poland and from the Gene Bank Gatersleben, Germany.

The *Erysiphe graminis tritici* (*Egt*) isolates used for the differentiation of the major known resistance genes were collected from different parts of Europe and selected from single spore progenies (FELSENSTEIN et al. 1991). The *Egt* isolates were classified under Weihenstephan accession numbers and maintained at the Institut für Pflanzenbau und Pflanzenzüchtung, Weihenstephan. The tests for mildew resistance were conducted on primary leaf segments cultured on 6 g L^{-1} agar and 35 mg L^{-1} benzimidazole in plastic boxes. Three major classes of host reaction were distinguished: r – resistant (0-20% infection relative to susceptible control cv. Kanzler), i – intermediate (30-50% infection), s – susceptible (>50% infection). In some cases the disease reactions were not uniform on the 12-16 plants for each of the cultivars tested and combined responses such as r,i or i,s were used for classification. Cultivars segregating for resistant or intermediate were classified as r/i. The methods of inoculation and conditions of incubation were applied according to HSAM and ZELLER (1997).

Cultivars were scored cytologically for the presence of satellited chromosomes in somatic mitoses by using the standard Feulgen method. Only two (6B) satellited chromosomes were expected for plants homozygous for the wheat rye translocation T1BL•1RS (ZELLER 1973). All cultivars with the disease response of *Pm8*, and those with two satellited chromosomes were further tested for the presence of secalin (Sec-R1) by acetic polyacrylamide gel electrophoresis (A-PAGE) according to the method of HSAM et al. (1995). In addition, these cultivars were tested for the presence of leaf rust resistance gene *Lr26* using an avirulent *Puccinia recondita* f. sp. *tritici* isolate W 303.

Results and discussion

For comparison of response patterns, eleven differential isolates of *Erysiphe graminis tritici* (*Egt*) were used to distinguish between host lines/cultivars with documented genes for resistance (Table 1). Cultivars Begra, Grana, Niwa, Izolda, Liwilla, Panda, Rosa, Wanda and five Polish accesions HTRI 1404, HTRI 154, HTRI 165, HTRI 1370, HTRI 4663 provided by the Gene Bank Gatersleben, Germany, gave a susceptible and susceptible/intermediate response to the 11 differential isolates of *Egt*.

Several cultivars were characterized by identical resistance patterns as the standard differential with documented resistance genes. Cultivars Kaja and Kobra were found to carry resistance gene *Pm2* (Table 2), as their responses to the *Egt* isolates corresponded to the pattern displayed by isogenic line Ulka/8*Cc (Table 1). This resistance can be traced back to the British cultivar

Table 1. Differential reactions of 20 wheat cultivars/lines carrying known powdery mildew resistance genes (*Pm*) after inoculation with 11 isolates of *Erysiphe graminis* f. sp. *trtici*

Cultivar/Line	*Erysiphe graminis tritici* isolate											*Pm*-genes
	W2	W5a	W6	W9	W10	W12	W13	W14	W15a	W16	W17	
Axminister/8*Cc[2]	r[1]	r	r	i,s	r	s	s	s	r	s	s	*1*
Ulka/8*Cc	s	s	r	s	r	s	s	s	r	s	s	*2*
Asosan/8*Cc	r	s	r	r	r	s	r	r	s	s	r	*3a*
Chul/8*Cc	r	r	s	r	r	r	r	r	s	r	i,s	*3b*
Sonora/8*Cc	r	i	s	i	r	s	r	i,s	s	s	s	*3c*
Kolibri	s	s	s	r	s	r	s	r	r	s	r	*3d*
W150	s	i,s	i,s	i	r	i,s	r	r,s	s	s	s	*3e*
Mich. Amb./8*Cc	r	s	s	i	r	s	r	i,s	s	s	s	*3f*
Khapli/8*Cc	s	s	s	r	i	r	s	s	i,s	s	i	*4a*
Armada	s	s	s	r	r	r	s	s	r	s	s	*4b*
Hope	s	s	s	s	r	s	s	r	s	s	s	*5*
TP114/2*Starke[3]	s	r	r,i	r	r,i	s	r,i	r,i	r	i	s	*6*
Maris Huntsman	s	r	r	r	r	s	r,i	r	r	i	s	*2+6*
Normandie	r	r	r	r	r	s	s	s	r	s	s	*1+2+9*
Disponent	r	s	s	r	s	r	s	s	s	s	r	*8*
BRG 3N[4]	r	r	r	r	r	r	r	r	r	r	r	*16*
Amigo	i	s	i,s	i	i	i	r	s	s	r	r	*17*
XX 186[5]	s	r	r	i	r	r	i	i	s	i	r	*19*
Virest	r	r	r	r	r	i	i,r	i	r	i,s	i,s	*22*
Chiyacao	r	r	r	r	r	r	r	r	r	r	r	*24*

[1] r – resistant, s – susceptible, i – intermediate

[2] Seven times backcrossed to Chancellor

[3] Once backcrossed to Starke

[4] BRG 3N/76-F2-205 – *T. turgidum* var. *dicoccoides* derivative

[5] XX 186 – *T. durum* × *Ae. squarrosa* hexaploid synthetic wheat line.

Table 2. Reactions of 56 wheat cultivars grown in Poland after inoculation with 11 differential isolates of *E. graminis tritici*

Cultivar	Growth habit	*Erysiphe graminis tritici* isolate											Postulated *Pm*- gene(s)
		W2	W5a	W6	W9	W10	W12	W13	W14	W15a	W16	W17	
Kaja	W	s	s	r	s	r	s	s	i	r	s	s	*2*
Kobra	W	s	s	r	s	r	s	s	s	r	s	s,i	*2*
Tatra	W	s	s	r	s	r	s	s	s	r	s	s/i	*2*
Zorza	W	s	s	r	s	r	s	s,i	s	r	s	i	*2*
Alkora	S	s	s	s,i	r	s	r	s	r	r	s	r	*3d*
Broma	S	s	s	s	s	r	s	s	r	s	s	s	*5*
Emika	W	s	s	s	s	r	s	s	r	s	s	s	*5*
Henika	S	s,i	s	s	i,s	r	s	s,i	r	s	s	s	*5*
Lanca*	W	r	s	s	r	s	r	s	s	s	s	r	*8*
Iławska	W	s	s	r	s	r	s	s,i	r	r	s	s	*2+5*
Alba	W	s	r	r	r	r	s	r	r	r	i	s	*2+6*
Almari	W	s	r	r	r	r	s	r/i	r	r	i	s	*2+6*
Arda	W	s	r	r	r	r	s	r	r	r	i	s	*2+6*
Astarte	W	s	r	r	r	r	i	r	r	r	i	s	*2+6*
Jubilatka	W	s.i	r	r	r	r	s	r	r	r	i	s,i	*2+6*
Juma	W	s	r	r	r	r	s	i/r	r	i/r	i	s	*2+6*
Kamila	W	s	r	r	r	r	s	r	i/r	r	i	s	*2+6*
Korweta	W	s	r	r	r	r	s	r	r	r	i	s	*2+6*
Lama	W	s	r,i	r,i	r	r	s	i/r	r	i/r	i	s	*2+6*
Maltanka	W	s	r	r	r	r	s	r	r	r	i	i,s	*2+6*
Oda	W	s	r	r	r	r	s	r	r	r	i	s	*2+6*
Olcha	W	s	r	r	r	r	s	r	r	r	i	s	*2+6*
Olma*	W	s	r	r	r	r	s	r	r	r	r	s	*2+6*
Opera	W	s	r	r	r	r	s	r	r,i	r	i	s	*2+6*
Rada	W	s	r	r	r	r	s,i	r	r	r	i	s,i	*2+6*
Roma	W	s	r	r	r	r	s	r	r	r	i	s	*2+6*
Sakwa	W	s	r	r	r	r	s	r	r	r	i	s,i	*2+6*

Weneda*	W	s	r	r	r	r	s	r	r	r	r	s,i	*2+6*
Gedania	W	s	s,i	r	r	r	r	s	r	r	s	i	*2+u*
Toba*	W	s	s	r	r	r	r	s	r	r	s	s	*2+u*
Gracja	S	s	s	i	r	r	r	i	r	r,i	s	r	*3d+4b*
Mona	S	s	s	s	r	r	r	s	r	r	s	r,i	*3d+4b*
Turnia*	W	r	s	s	r	r	r	s	i	r	s	r	*3d+8*
Eta	S	s	s	r	r	r	r	r	r	r	s	r	*3d+u*
Hena	S	s	s	r	r	r,i	r	r	r,i	r,i	s	r,i	*3d+u*
Jasna	S	s	s	r	r	r,i	r,i	i,s	i	i,r	s	r	*3d+u*
Jota	S	s	i,s	r	r	r	r	r	r	r	s	r	*3d+u*
Wilga*	W	r	s	s	r	r	r	s	s	r	s	r	*4b+8*
Aleta*	W	r	s	s	r	r	r	i	r	s	s	r	*5+8*
Santa	S	s	s	s	r	r	s	s	r	s	s	s	*5+u*
Torka	S	r	s	r	r	r	s	r,i	r	i,s	s	s	*5+u*
Jawa	W	i,r	r	r	s,i	r	i,s	r	r	r,i	r,i	i	*1+2+u*
Hezja	S	r	r	r	r	r	r	i	r	r	s	r	*1+3d+4b*
Omega	S	r	r	r	r	r	r	i	r	r	s	r	*1+3d+4b*
Polna	S	s	s	r	r	r	r	i	r	r	s	r	*2+3d+4b*
Elena	S	s	r	r	r	r	r	r	r	r	r	s	*2+6+u*
Igna	S	r	r	r	r	r	r	i	r	r	r	r	*3d+4b+u*
Helia	S	r	r	r	r	r	r	i	i,s	r	s	s,i	*1+2+9+4b*
Hera	S	s	s	s	r	r	s	i	i	s	s	s	*u*
Nike	W	s	r	r	r,i	r	i	r	i,r	i,s	s	r	*u*
Gama	W	i,r	i	r	i	i,r	s	r	r	i,r	i	s	*u*
Kontesa	S	i,s	s	r	r	r	r	r	r	r	s	r	*u*
Banti	S	r	r	r	r	r	r	r	r	r	r	r	*u*
Ismena	S	r	r	r	r	r	r	r	r	r	r	r	*u*
Ilona	S	r	r	r	r	r	r	r	r	r	i,r	r	*u*
Sigma	S	r	r	r	r	r	r	r	r	r	r	r	*u*

*Plants with only one pair of satellited chromosomes instead of two pairs in root tip; mitotic cells; r/i – segregating for resistant and intermediate; s/i – segregating for susceptible and intermediate; r – resistant; i – intermediate; s – susceptible; S – spring; W – winter

Maris Huntsman which is in the pedigrees of these cultivars and carries the combination of genes *Pm2* + *Pm6* (Tables 1 and 3). The presence of *Pm2* in Kobra is in agreement with earlier results of GORDEI et al. (1998). Cultivars Tatra and Zorza also carried resistance gene *Pm2*. However, the source of the resistance cannot be determined from the pedigree. One cultivar, Alkora, showed a response pattern indicative of the presence of resistance gene *Pm3d*. This gene appears to have been inherited either from the German spring wheat cultivar Kolibri or the Czech cultivar Jara, as both of them carry *Pm3d* (LUTZ et al. 1992, ZELLER et al. 1993a). Three cultivars, Broma, Emika and Henika showed the same response pattern as differential cultivar Hope (Table 1) which is known to carry *Pm5*. Broma as well as Henika may have received their resistance gene from spring wheat cultivar Selpek, known to have *Pm5* (HEUN, FISCHBECK 1987). In the pedigree of cv. Emika there is cultivar Perdix (Table 3) which is a hybrid between Heine 2167.50 and Heine VII. It is very likely that the breeding strain Heine 2167.50 is the donor of resistance gene *Pm5* in cv. Emika and several German winter wheat cultivars such as Falke, Kormoran, Reiher and Sperber (HEUN, FISCHBECK 1987).

Cultivar Lanca showed the same response pattern as differential cultivar Disponent (Tables 1 and 2) carrying resistance gene *Pm8* from *Secale cereale*. In the pedigree of Lanca there is the Bulgarian wheat cultivar Nadzieja (Table 3), which is known to have derived its wheat-rye T1BL•1RS translocation from Avrora (SCHLEGEL 1997). Somatic chromosomes of Lanca are characterized by the presence of only two satellited chromosomes (6B), indicating the deficiency of the short arms of satellited chromosome pair 1B, which has been replaced by rye chromosome arm 1RS. The presence of the T1BL•1RS translocation in Lanca is corroborated by cytological evidence (TARKOWSKI, APOLINARSKA 1992) and the detection of leaf rust resistance gene *Lr26* (BARTOŠ 1990). Cultivar Ilawska was characterized by the combined resistance genes *Pm2* and *Pm5*. *Pm2* may have been derived from Maris Huntsman (Table 3), but the origin of *Pm5* remains unknown.

The response pattern of a group of eighteen cultivars corresponded to that of differential cultivar Maris Huntsman, known to have the combined resistance genes *Pm2* + *Pm6* (Tables 1 and 2). Maris Huntsman is in the pedigree of cultivars Alba, Almari, Arda, Jubilatka, Juma, Lama, Maltanka, Oda, Olma, Opera, Rada and Roma (Table 3) and may have conferred resistance genes *Pm2* and *Pm6*. The same genes in cultivar Olcha may have been inherited from Maris Fundin which is known to have this gene combination (McINTOSH 1988). However, the origin of the *Pm2* + *Pm6* gene combination in cultivar Astarte cannot be determined, because no information on resistance of the par-

ents is available. Olma had only two satellited somatic chromosomes in root tip cells characteristic for the presence of the wheat-rye chromosome translocation T1BL•1RS. As Kavkas is in the pedigree of Olma (Table 3), it is very likely that the T1BL•1RS translocated chromosome pair has been derived from this cultivar. However, resistance gene *Pm8*, which is generally located on the short rye chromosome arm, was not expressed in cultivar Olma (Table 2), whereas Sec-R1 and *Lr26* were detected. Also cultivar Weneda is characterized by a response pattern corresponding to wheat lines that have the combination of resistance genes *Pm2* + *Pm6* (Table 2). Weneda also carried only two satellited chromosomes in root tip mitotic cells indicating the presence of the T1BL•1RS translocation which may have been derived from cultivar Kavkas (SCHLEGEL 1997, Table 3). In addition, Weneda showed *Sec-R1* for secalin and *Lr26* for leaf rust resistance. The presence of *Lr26* is in support of BARTOŠ (1990) who earlier reported that cv. Weneda has this gene. It appears that also Weneda carries a gene which suppresses the expression of powdery mildew resistance gene *Pm8* known to be located on chromosome arm 1RS. Suppression of *Pm8* resistance was reported in several wheat cultivars grown in Central Europe by HANUŠOVÁ et al. (1996), attributed to a gene designated *SuPm8* and located on chromosome 7D (ZELLER, HSAM 1996). The origin of the resistance genes *Pm2* + *Pm6* in cultivars Kamila, Korweta and Sakwa cannot be determined, because no information on the parents is available.

Cultivar Gedania showed the response pattern of *Pm2* and additional unknown resistance, but the origin remains unknown (Table 3). Cultivar Toba also displayed the response pattern of resistance gene *Pm2* and an unknown gene. As cultivar Lanca can be ruled out as the donor of the resistance, the breeding line MG 80.241 (Table 3) might have contributed the additional resistance to powdery mildew. However, Lanca is very likely to have contributed the T1BL•1RS translocation, as verified by the presence of only two satellited chromosomes in root tip cells of cv. Toba. Furthermore, this cultivar has also genes *Lr26* and *Sec-R1*, characteristic for the 1RS rye arm. Since the resistance of gene *Pm8* is not expressed in cv. Toba, the efficacy of suppressor gene *SuPm8* in this cultivar is postulated.

Cultivars Gracja and Mona, which have resistance genes *Pm3d* and *Pm4b*, may have derived *Pm3d* from Kolibri, Jara or Kadett and *Pm4b* from Kadett. In cultivar Turnia, only two satellited chromosomes in the root tip cells were observed, indicating a T1BL•1RS translocation with the *Pm8* resistance gene. In addition, Turnia also showed *Sec-R1* and leaf rust resistance gene *Lr26*. However, the origin of the wheat-rye translocated chromosome and gene *Pm3d* cannot be determined from the pedigree.

Table 3. Genealogies of tested Polish common wheat cultivars

Cultivar	Pedigree
Alba	Weique/Dańkowska Biała//Luna/2/Grana/3/Maris Huntsman
Aleta	Emika/Maris Huntsman
Alkora	Kolibri/Alfa//Jara
Almari	Maris Huntsman/Alcedo
Arda	Maris Huntsman/C 474-73
Astarte	C-473-73/Maris Hobbit
Banti	Timmo/Jara//Kadett/Wz6154
Begra	Grana/Besostaya 1
Broma	Ostka Popularna/S.227//Selpek
Emika	Etoile de Choisy/Mironovskaja 808//Perdix
Elena	STH 1262/SMH 1320 STH 1262 = Jubilejnaya 50/Maris Huntsman/2/Hohenthurm 8179//Grana SMH 1320 = NS 736/Mironovskaya 808//Maris Huntsman
Eta	Kolibri/Alfa//Jara
Gama	Mironovskaya 808/Luna
Gedania	DED 739-75/St 129-76//CHD 537-77
Gracja	Olesen/WW12128/2/Alfa/Kolibri//Jara/3/Kadett
Grana	Etoile de Choisy/Wysokolitewka Sztywnosłoma//Dańkowska Biała
Helia	Bb 4/Sappo//Selpek/2/WW 17328/3/Kadett
Hena	Eta/Jota
Henika	CB 412/*Selpek
Hera	Hadmerslebener38662-69/Jara
Hezja	Cebecco 1182/Kadett
Igna	Kadett/Jara
Ilawska	Maris Huntsman/Krasnodarska 39//Mironovskaya 808/Luna
Ilona	Timmo/Jara//Kadett/Wz6154
Ismena	Kolibri/Alfa//Hermes/2/Jara
Jasna	Eta/Kokart
Jawa	Eureka/Grana//Cebecco72/Sylvia
Jota	Hadmerslebener38662-69/Jara
Jubilatka	Maris Huntsman/Niwa/2/Orla/Niwa//DED 739-75
Juma	Mironovskaya Jubilejna/*Maris Huntsman
Kaja	Liwilla/Maris Huntsman
Kamila	Kranich/WW 153-1//Beta
Kobra	Maris Huntsman/Krasnodarska 39//Mironovskaya 808/Luna
Kontesa	RAH 526/Mex 14
Korweta	CHD 3672-72-77/Gama
Lama	Maris Huntsman/Jana//ród C 474-73

Cultivar	Pedigree
Lanca	Nadzieja/Pluto
Maltanka	Kavkas/Grana//Maris Huntsman
Mona	Kolibri/Alfa//Jara/2/Kadett
Nike	Maris Huntsman//NS-736/Mironovskaya 808
Oda	S-318-72/Maris Huntsman
Olcha	Maris Fundin/Extrem
Olma	Kavkas/Grana//Maris Huntsman
Omega	Kadett/Jara
Opera	Maris Huntsman/S 282//TAW38667173
Polna	Olesen/WW 12128//Selpek/Bastion/2/Kadett
Rada	Kranich/C568-70//Luna/Mironovskaya 808/2/Maris Huntsman
Roma	AR-112-74/Maris Huntsman//Niwa/Maris Huntsman
Sakwa	SMH 1321/UH 318//STH 1527
Santa	L. mex 97-3 /Selpek//Kolibri/2/Henika
Sigma	Kalyansona/Sappo
Tatra	Bocquiau/Kranich//Fakir/Nadadores 63/2/TAW 25880-71
Toba	MG 80.241/2/Lanca
Torka	William/RR 277-78//WW 19018
Turnia	Polanka/DED 739-75//Polanka/TAW 6505-74 Polanka = Kranich/Hohenthurm 10690-62; DED 739-75 = Fakir/Kato//MG 1669
Weneda	Kavkas/Tetrix//C 1073-67
Wilga	Juwel/Lanca
Zorza	TAW 13763-76/P3567-73

Cultivars Eta, Hena, Jasna and Jota were characterized by the response pattern of the combination of resistance gene *Pm3d* and an unknown gene which confers additional resistance to isolates numbers W6, W10 and W13. It is assumed that cv. Eta, which is in the pedigrees of cvs. Hena and Jasna, has inherited *Pm3d* from cultivars Kolibri or Jara (Table 3). Cultivar Kokart in the ancestry of Jasna does not carry any major resistance gene (HEUN, FISCHBECK 1987). Cultivar Jota may have received *Pm3d* from Jara (LUTZ et al. 1992). Cultivar Wilga has most likely derived its resistance genes *Pm4b* from Juwel and *Pm8*, together with the T1BL•1RS wheat-rye translocation, also from Juwel (HEUN, FISCHBECK 1987) or from cultivar Lanca (TARKOWSKI, APOLINARSKA 1992). Cultivar Aleta showed the presence of two satellited chromosomes in root tip cells and the response pattern of the combined genes *Pm5* + *Pm8*. The origin of the resistance genes remains obscure, since neither Emika nor Maris Huntsman in their pedigrees have either *Pm5* or *Pm8* (Table 3). However, it is possible that a previous biotype of Emika possesed

the T1BL•1RL translocated chromosome together with resistance gene *Pm8*. Cultivar Santa appears to have resistance gene *Pm5* from cv. Henika or Selpek and additional unknown resistance. The origin of *Pm5* in cultivar Torka cannot be determined, as no information on the resistance of its parents is available.

Cultivar Jawa apparently carried resistance genes *Pm1*, *Pm2* and an unknown resistance gene. This cultivar was reported to have genes *Pm1*, *Pm2* and *Pm6* by GORDEI et al. (1998). However, it cannot be determined which parent has donated the resistance genes. Cultivars Hezja and Omega displayed resistance patterns of genes *Pm1* + *Pm3d* + *Pm4b* in a combination (Tables 1 and 2). The resistance genes *Pm3d* and *Pm4b* may have been derived from Kadett (Table 3), however, the origin of gene *Pm1* cannot be determined. The resistance of cultivar Polna was characterized by the response pattern of the combination of genes *Pm2*, *Pm3d* and *Pm4b*. From the pedigree of the cultivar it can be deduced that *Pm3d* and *Pm4b* may have been derived from Kadett (Table 3), although, the origin of *Pm2* remains unknown.

Cultivar Elena is characterized by the reaction of genes *Pm2* + *Pm6* and additional unknown resistance in combination. Maris Huntsman may have contributed resistance genes *Pm2* and *Pm6* (Table 3). Cultivar Igna was found to carry resistance genes *Pm3d* and *Pm4b*, combined with an additional unknown resistance gene or genes. Genes *Pm3d* and *Pm4b* were most probably derived from cultivar Kadett (Tables 2 and 3).

Cultivar Helia showed the resistance patterns of genes *Pm1*, *Pm2*, *Pm4b* and *Pm9* (Table 2). According to its pedigree (Table 3), Helia may have derived the resistance genes from Sappo, known to carry this gene combination (HEUN, FISCHBECK 1987). Cultivars Gama, Hera and Kontesa displayed resistance to several isolates which could not be attributed to documented resistance genes, and also could not be deduced from the parentage. The origin of the resistance of cultivar Nike may be postulated to have been derived from Maris Huntsman. Another accession of Nike grown in Belorus and previously tested by GORDEI et al. (1998) showed a response pattern which indicated the presence of *Pm2* and an unknown resistance gene. Two cultivars, Sigma and Ismena, exhibited resistance to all mildew isolates employed. Sigma may have derived its resistance from cultivar Sappo plus an unknown gene (Table 3). Cultivar Ismena might have received resistance gene *Pm3d* from Kolibri or Jara, *Pm4b* from the German cultivar Hermes (HEUN, FISCHBECK, 1987) and an unknown source.

Cultivars Banti and Ilona, both having the same pedigree, were resistant to all the tested isolates. It appears that the cultivars possess a combination of resistance genes which may involve *Pm1* + *Pm3d* + *Pm6*, possibly derived

from Swedish cultivar Timmo, described to carry genes *Pm1*, *Pm2*, *Pm4b* and *Pm6* (HOVMØLLER 1989), and *Pm3d* from cultivar Jara or Kadett (Table 3).

The present study reveals the extent of genetic variation of powdery mildew resistance in wheat cultivars grown in Poland. However, the genes currently deployed in commercial cultivars correspond to resistance genes common in cultivars grown in other European countries (ZELLER et al. 1993b). In Poland, relatively high virulence frequencies in wheat powdery populations against the most often used resistance genes and their combinations were observed. The highest virulence frequencies were found for *Pm1*, *Pm2*, *Pm5* and *Pm8*, increased virulences to resistance genes *Pm4b* and the combination of *Pm2* + *Pm6* and *Pm4b* + *Pm8* were also detected (WOŹNIAK-STRZEMBICKA, ŁAZARSKA 1994).

The increase in virulence frequencies may be partly explained by the widespread distribution of genes *Pm2* + *Pm6* derived from cv. Maris Huntsman in many Polish cultivars. It is apparent that the resistance genes currently distributed in the commercial wheat cultivars and the increased virulences of the pathogens to the currently deployed resistance genes (STRZEMBICKA, ŁAZARSKA 1996, WĘGRZYN et al. 1994) do not provide sufficient protection against the contemporary pathogen populations in Poland. Therefore novel sources of resistance are needed to combat the mildew disease.

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