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Identification of powdery mildew resistance genes in common wheat (*Triticum aestivum* L. em. Thell.). X. Cultivars grown in Belarus and neighbouring countries

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Abstract. Sixty-six wheat cultivars grown in Belarus, Poland, Russia and the Ukraine were tested for mildew response to a collection of 11 different isolates of *Erysiphe graminis* DC f. sp. *tritici* Marchal. Nineteen cultivars have shown a susceptible reaction and eighteen were characterized by susceptible or intermediate responses. Fourteen cultivars revealed isolate-specific response patterns that could be attributed to major known resistance genes or gene combinations. Twelve cultivars have one documented gene: *Pm5* in eight cultivars, *Pm2* in two cultivars and *Pm8* also in two cultivars. One cultivar has two genes (*Pm2* + *Pm6*), while another cultivar carries a combination of three genes (*Pm1* + *Pm2* + *Pm6*). Fifteen cultivars were characterized by response patterns not documented so far or by a known resistance response combined with an undocumented resistance. Apparently three cultivars with the T1BL.1RS wheat-rye translocation have a gene suppressing the *Pm8* mildew resistance. One cultivar was resistant to all the used isolates. Its resistance might be conditioned by an unknown major gene or combination of genes.

Key words: powdery mildew, resistance genes, *Triticum aestivum*, wheat cultivars.

Introduction

The powdery mildew disease caused by *Erysiphe graminis* DC f.sp. *tritici* Marchal is a major constraint to wheat production and optimum wheat yields

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worldwide. Utilization of resistant wheat cultivars provides an effective and environmentally sound alternative to chemicals used in powdery mildew control. However, in Western and Central Europe the efficacy of best-known resistance genes currently in use is more or less exhausted (LUTZ et al. 1992, 1995, ZELLER et al. 1993b). Information on wheat mildew resistance in Eastern European countries is very scarce (BABAYANTS et al. 1985, LEBEDEVA 1985,1994, MORGUNOV 1992), so novel sources of resistance and evaluation of their potential usefulness are urgently needed. So far, 24 loci for resistance to powdery mildew (*Pm1-Pm24*) have been assigned to specific chromosomes (MCINTOSH et al. 1996, HUANG et al. 1997b). The objective of the present study is to provide information about the occurrence of resistance genes in wheat cultivars grown in Belarus, Poland, Russia and the Ukraine.

Material and methods

Seeds of sixty-six wheat cultivars grown in Belarus, Poland, Russia and the Ukraine were provided by the Institute of Arable Farming and Fodder, Zhodino, Belarus; Institute of Genetics and Cytology, Minsk, Belarus; Plant Breeding and Acclimatization Institute, Radzików, Poland; Institute of Agriculture, Belgorod, Russia and Mironovskaya Research Station, Mironovka, Ukraine, respectively. The near-isogenic lines of Chancellor with known mildew resistance genes (BRIGGLE 1969) and TP 114, twice backcrossed with cultivar Starke (JØRGENSEN, JENSEN 1972), having the resistance gene *Pm6* and W150, and an old Australian wheat cultivar (MCINTOSH, BAKER 1966), were kindly provided by R.A. MCINTOSH, Australia.

All cultivars were verified by chromosome counts for detection of the number of satellited chromosome pairs (1B, 6B) using the standard Feulgen method.

The tests for powdery mildew resistance were carried out on segments of primary leaves from host plants grown in a phytotron. The leaf segments were placed in Petri-dishes on 6 g L^{-1} agar with 35 mg L^{-1} benzimidazole. The *Erysiphe graminis tritici* (*Egt*) isolates used for discrimination of the resistance genes were collected in several European countries and selected from single spore progenies (FELSENSTEIN et al. 1991). The presented results were based on the evaluation of at least three replications each consisting of four plants. The methods applied for inoculation of the leaf segments and disease assessment were previously described by ZELLER et al. (1993a). Table 1 shows host-pathogen interactions of seven near-isogenic wheat lines and fourteen cultivars/lines carrying known major resistance genes and gene combinations

Table 1. Common wheat (*Triticum aestivum*) cultivars grown in Belarus, Poland, Russia and the Ukraine showing susceptible and susceptible or intermediate reactions to 11 isolates of *Erysiphe graminis tritici*

Susceptible cultivars	Cultivars showing susceptible and intermediate response
Belorusskaya-3	Berezina
Bylina	Belorusskaya-25
Belozornaya	Belorusskaya-80
Grodnenskaya-10	Festivalnaya
Grodnenskaya-23	Garmoniya
K-3	KP-82
Nadzeya	Kupalinka
Nemchinovskaya-25	MSN-14
Nemchinovskaya-110	Pogoniya
Natalka	Slavuta
Mironovskaya-40	Suzore
Mironovskaya-60	Turovchanka
Mironovskaya-808	Nemchinovskaya-1
Mironovskaya Niskorolaya	Nemchinovskaya-4
Mironovskaya Ostistaya	Belgorodskaya-13-90
Stepniak	Pamjat Fedina
Peresvet	Ivolga
Odesskaya-66	Mironovskaya-19
Panda	

for resistance to powdery mildew after inoculation with 11 mildew isolates. Three major classes of host reaction were distinguished: r – resistant, i – intermediate and s – susceptible. The combined classifications – r,i and i,s – indicate that both reactions were observed.

Results and discussion

Among the 66 tested wheat cultivars, 19 showed susceptible responses to all the used mildew isolates. A total of 18 cultivars were characterized by susceptible and intermediate responses to some isolates (Table 1). The response patterns of 29 other wheat cultivars to 11 isolates of *Egt* showed response patterns characteristic to already known resistance genes and to resistance patterns which have not been documented yet. Two cultivars, Lutskovlyanka and Kobra, showed a resistance pattern (Table 3) characteristic of *Pm2*, corresponding well with the pattern of near-isogenic tester line Ulka/8*Cc (Table 2). A group of eight cultivars: Kapylyanka, Kapylyanka-2, Karavay, Padarunak, Belgorodskaya 15-90, Belgorodskaya 16-90, Polesskaya-90 and Shchedraya

Table 2. Differential reactions of 21 common wheat (*Triticum aestivum*) cultivars and lines possessing powdery mildew (*Pm*) resistance genes, inoculated with 11 isolates of *Erysiphe graminis* f. sp. *tritici*

Cultivar/ line	Resistance gene (*Pm*)	*Erysiphe graminis tritici* isolates										
		2	5	6	9	10	12	13	14	15	16	17
Axminst/8*Cc[2]	1	r[1]	s	r	i, s	r	s	s	s	r	s	s
Ulka/8*Cc	2	s	r	r	s	r	s	s	s	s	s	s
Asosan/8*Cc	3a	r	s	r	r	r	s	r	r	s	s	i
Chul/8*Cc	3b	r	s	s	r	r	r	r	r	s	r	i, s
Sonora/8*CC	3e	r	s	s	i	r	s	r	i, s	s	s	s
Kolibri	3d	s	s	s	r	s	r	s	r	r	s	r
W150	3e	s	i, s	i, s	i	r	i, s	r	r, i	s	s	s
Mich.Amb/8*Cc	3f	r	s	s	s	r	s	r	i, s	s	s	s
Khapli/8*Cc	4a	s	r	s	r	i	r	s	s	i	s	i
Armada	4b	s	r	s	r	r	r	s	s	r	s	s
Hope	5	s	s	s	s	r	s	s	r	s	s	s
TP 114/St.2[3]	6	s	r, i	r, i	r	r, i	s	r, i	r, i	r, i	i	s
Disponent	8	r	s	s	r	s	r	s	s	s	s	r
BRG 3N[4]	16	r	r	r	r	r	r	r	r	r	r	r
Amigo	17	i	i	i, s	i	i	i	r	s	i	r	r, i
M1N	18	r	r	r	r	r	r	r	r	r	r	r
XX 186[5]	19	s	s	r	i	r	r	i	i	s	i	r
6AL/6VS[6]	21	r	r	r	r	r	r	r	r	r	r	r
Virest	22	i	i	r	r	r	i	i, r	i	r	i, s	i, s
81-7241	23	r	r	s	r	r	r	s	i	i	s	i
Chiyacao	24	r	r	r	r	r	r	r	r	r	r	r

[1] r – resistant, s – susceptible, i – intermediate
[2] seven times backcrossed to Chancellor
[3] twice backcrossed to Starke
[4] BRG 3N/76-F_2-205, a derivative of *T. turgidum* var. *dicoccoides*
[5] a hexaploid synthetic wheat line *Triticum durum* × *Ae. squarrosa*
[6] wheat-*Haynaldia villosa* translocation line

Polesya appear to carry resistance gene *Pm5*. KP-202 and Mironovskaya-61 exhibited the response pattern of *Pm8* when compared to the pattern of Disponent in Table 2. Cultivar Bulava was characterized by the combination of resistance genes *Pm2* and *Pm6*, while cultivar Jawa by a response pattern identical to the pattern of a combination of resistance genes *Pm1* + *Pm2* + *Pm6*. Five cultivars showing disease responses of documented resistance combined with an unknown (*u*), and new resistance gene combinations were observed: *Pm2* + *u* (Nike and Polesskaya-87), *Pm5* + *u* (Malanka and Mirleben) and *Pm8* + *u* (Belorusskaya-129). Unfortunately, information on the resistance genes of cultivars involved in the pedigrees of the tested material was not available and hence pedigrees are not presented.

Table 3. Reactions of 29 common wheat (*Triticum aestivum*) cultivars grown in Belarus, Poland, Russia and the Ukraine inoculated with 11 different isolates of *E. graminis* f. sp. *tritici*

Cultivar and origin	*Erysiphe graminis tritici* isolates											Postulated resistance gene
	2	5	6	9	10	12	13	14	15	16	17	Pm
BELARUS												
Lutskovlyanka	s[1]	r	r	s	r	s	s	s	s	s	s	2
Bulava	s	r	r	r,i	r	s	r.i	r	r	r	s	2+6
Kapylyanka	s	s	s	s	r	s	s	r	s	s	s	5
Kapylyanka-2	s	s	s	s	r	s	s	r	s	s	s	5
Karavay	s	s	s	s	r	s	s	r	s	s	s	5
Padarunak	s	s	s	s	r	s	s	r	s	s	s	5
Malanka	r,s	s	s	r	r	s	s	r	s	s	s	5+u[2]
KP-202	r	s	s	r	s	r	s	s	s	s	r	8
Mironovskaya-61	r	s	s	r	s	r	s	s	s	s	r	8
Belorusskaya-129	r	s	s	r,i	r	r	s	s	s	s	r,i	8+u
Diana	s	s	r,s	s	r	s	s	r	s	s	s	u
Belorusskaya-4	s	s	s	s	r	r	s	s	s	s	s	u
Slonimchanka	s	s	s	s	r	r	s	s	s	s	s	u
Viza	r	r,i	r	r	r	r	r	r	r	r	r	u
POLAND												
Kobra	s	r	r	s	r	s	s	s	s	s	s	2
Nike	s	r	r	s	r	s	r	r,i	r	s	s	2+u
Jawa	r,i	r	r	r,s	r	s	r	r	r,i	r,i	s	1+2+6
RUSSIA												
Belgorodskaya 1590	s	s	s	s	r	s	s	r	s	s	s	5
Belgorodskaya 1690	s	s	s	s	r,i	s	s	r,i	s	s	s	5
Rita	s	s	s	s	s	r	s	s	s	s	s	u
UKRAINE												
Polesskaya-87	s	r	r	s	r	s	s	r,i	r	r	s	2+u
Polesskaya-90	s	s	s	s	r,i	s	s	r	s	s	s	5
Shchedraya Polesya	s	s	s	s	r	s	s	r	s	s	s	5
Mirleben	s	s	s	s	r	r	s	r,i	s	s	s	5+u
Albatros	s	r,i	s	s	s	s	r,i	s	s	s	s	u
Mironovskaya-27	s	s	s	s	r	r	s	s	s	s	s	u
Mironovskaya-30	s	r,i	s	s	r	r	s	s	s	s	s	u
Olympiya	s	s	s	s	r	s	s	s	s	s	s	u
Yuna	s	s	s	s	r	s	s	s	s	s	s	u

[1] r – resistant, s – susceptible, i – intermediate
[2] undocumented resistance

Undocumented resistance was also found in several other cultivars. Cultivar Rita showed a resistance response to a single *Egt* isolate No. 12, while cultivars Olympiya and Yuna to isolate No. 10, respectively. Cultivars Belorusskaya-4, Slonimchanka and Mironovskaya-27, exhibited resistance response against isolates Nos. 10 and 12, while cultivar Albatros showed resistance to isolates Nos. 5 and 13. Cultivar Diana was characterized by a resistance response to *Egt* isolates Nos. 6, 10 and 14, while Mironovskaya-30 by resistance to isolates Nos. 5, 10 and 12, respectively. Cultivar Viza (pedigree: Belorusskaya-80/Diamant) was the only candidate in the collection that showed resistance to all the tested *Egt* isolates. As Belorusskaya-80 exhibited susceptible and intermediate response after inoculation and Diamant was resistant only to isolates Nos. 12, 13 and 14 (data not shown) the resistance in Viza cannot be traced back to the parents given. An outcrossing event or an unmentioned line in the pedigree may account for this outstanding resistance.

Wheat cultivars Mironovskaya-60 and Mironovskaya Ostistaya developed in the Mironovskaya Research Station, Mironovka, Ukraine, are characterized by a susceptible response to all the used *Egt* isolates. This is also true for the cultivar Nadzeya produced in the Institute of Arable Farming and Fodder, Zhodino, Belarus. All these cultivars are assumed to carry a T1BL.1RS wheat-rye translocation or substitution, as they were found to possess only two satellited chromosomes instead of four. This implies that the short arm of one satellited chromosome, presumably 1B, has been replaced by the 1RS rye chromosome arm. It is generally known that mildew resistance gene *Pm8* is located on the rye arm of this translocated chromosome. It seems that these cultivars possess a gene able to suppress the expression of *Pm8* resistance. Non-expression of this gene has already been described by FRIEBE et al. (1989), JÖNSSON (1991), HANUŠOVÁ (1992), LUTZ et al. (1992, 1995), BIMB, JOHNSON (1996). A detailed study on the mode of inheritance of the suppressor gene was given by HANUŠOVÁ et al. (1996) indicating that the suppressor is widespread in European wheat cultivars. A recent study by ZELLER, HSAM (1996) has shown that the suppressor gene is located on wheat chromosome 7D.

It appears that the phenomenon of suppression of resistance gene *Pm8* is widespread in European wheat cultivars. HUANG et al. (1997a) also found suppression of *Pm8* in numerous cultivars grown in China. However, this suppressor gene is not able to inhibit the expression of other known powdery mildew resistance genes, e.g., *Pm2* and *Pm4b* (HANUŠOVÁ et al. 1997).

Conclusions

Currently, in Belarus and neighbouring countries (Poland, Russia, the Ukraine) wheat breeding has been using only a few major resistance genes to powdery mildew. These genes are occurring individually or in combination in various cultivars. This is also true in Western and Central Europe (ZELLER et al. 1993b). With the exception of Belorussian cultivar Viza several cultivars show specific resistance to one, two or three *Egt* isolates. However, so far there has been no information on the number and efficiency of these genes being involved in the resistance. Most of the mildew resistance genes introduced into European wheat cultivars have lost their efficacy (FELSENSTEIN et al. 1991), so it is necessary to introduce novel sources of resistance. The resistance response pattern of Belorussian wheat cultivar Viza is remarkable. The association of the gene(s) conferring the resistance of this cultivar to their corresponding chromosomes is currently being under investigation. From the present study it was concluded that this limited number of resistance genes which occur in cultivars grown in Belarus, Poland, Russia and Ukraine (*Pm1*, *Pm2*, *Pm5*, *Pm6*, *Pm8*) is not sufficient for further resistance breeding. There is a need of genetic investigations of cultivars possessing undocumented resistance which can serve as a new genetic resource for the development of successful cultivars in the future.

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