Powdery Mildew Resistance of Winter Barley Varieties in Czech Official Trials

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Abstract: In 1996–2005, resistance to powdery mildew was studied in 167 winter barley varieties (of them 83 two-rowed and 84 six-rowed, 45 Czech and 122 foreign ones) included in the Czech Official Trials in that period. Seventeen known resistances to powdery mildew were identified (Ar, Bw, Di, Dr, Dt, Ha, HH, Ch, IM9, La, Lu, Ly, Ra, Ru, Sp, St and We). Unknown resistances were found in 25 varieties, in six of which (= 3.6% of all the examined set) they were effective to all used pathotypes of the pathogen. Six varieties exhibited heterogeneity in the examined trait, i.e. they are composed of lines with different resistances to powdery mildew. The most frequent resistances in the set were Ra, which was detected in 89 varieties (= 53%), and Bw was found in 30 varieties (18%). The resistances Sp, Ly, Ha, HH and Ch were also frequent. However, the frequency of the last three resistances cannot be quantified since we were not able to identify these resistances during the whole examined period.

Keywords: *Blumeria graminis* f.sp. *hordei*; *Erysiphe graminis* f.sp. *hordei*; *Hordeum vulgare* L.

On average of 1971–1977, winter barley (*Hordeum vulgare* L.) accounted for 1% (ca. 6000 ha) of the total area under barley in the Czech Republic (Dreiseitl & Jurečka 2003). Later, the planting area of the crop was rapidly enlarged up to 243 000 ha in 1991 (= 42% of the total area of barley), which was connected with the registration of foreign varieties with improved economically important traits, above all frost hardiness, and later with the registration of Czech varieties that were developed on the basis of the variety Borwina. At present, foreign varieties dominate in the Czech assortment both by the number of registered varieties and by the percentage of planting area. Six-rowed varieties were grown only, however the area of two-rowed varieties has been extended recently, being about one fourth of the area of winter barley. As for two-rowed varieties, only foreign varieties have been registered.

Less attention has been paid to the breeding of winter barley for resistance to powdery mildew, caused by *Blumeria graminis* (DC.) Golovin ex Speer f.sp. *hordei* Em. Marchal (= *Bgh*), compared to spring barley (Dreiseitl & Jørgensen 2000). After the expansion of winter barley in the 1980s, susceptible varieties of the crop could considerably contribute to accelerated adaptation of the pathogen and breakdown of some resistances in spring barley (Dreiseitl 2003). The area of the winter type is about one fourth of the total barley area, and non-resistant varieties provide favourable conditions for all-the-year-round reproduction of the pathogen. Therefore, it is reasonable to stress a complex of problems associated with the resistance of winter barley to powdery mildew.

The objective of this paper was to identify specific resistances to powdery mildew possessed by winter barley varieties that were tested in the Czech Of-

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Table 1. One hundred and sixty-seven varieties of winter barley included in the Czech Official Trials in 1996–2005 and their resistance to powdery mildew

Variety	R[1]	C[2]	Resistance[3]	Variety	R	C	Resistance
96/2716	2	D	Ly	Himalaya	2	D	U(E) Ra
133-12 B	6	D	Sp Ra	HM 35	6	CZ	Bw
370-BC	6	F	Sp Ra Ha	HM 403	6	CZ	Bw
3414/98	2	D	Ra Dr	HM 405	6	CZ	Bw Ra
AC 92/689/10 V	2	D	U	HM 407	6	CZ	H
AC 1276/12 A	2	D	Sp Ra	HM 515	6	CZ	Ra
Astrid	2	D	Ra	HM 788	6	CZ	Bw Ra
Ayla	2	SE	U	HM 791	6	CZ	Ra
BE 141601	6	D	Ra HH	Intro	2	NL	La
Bombay	2	D	Ar Ra	Julia	6	D	Ru
Boreale	2	F	Ha Ra	Juliane	6	F	Sp
Br. 789a86	2	D	Ra	Jura	2	D	Ly
Br. 2611m	2	D	Ly U	KM 103	2	CZ	None
Br. 3344a9	2	D	Ly	KM 237	6	CZ	Ra
Br. 4053c35	2	D	Ly	KM 791	6	CZ	Bw
Br. 4597i	2	D	Ha Ra	KM 906	6	CZ	Sp Bw Ra
Cebeco 00265-07	2	NL	Ra	KM 999	2	CZ	We U
Cebeco 01272	2	NL	H	KM 999/04	2	CZ	We U
Cebeco 01274	2	NL	Ch	KM 1318	2	CZ	U
Cebeco 01287	2	NL	Ly	KM 1318-303	2	CZ	U
Cebeco 03257-0202	2	NL	Ha Ra	KM 1428	6	CZ	H (Bw Ra)
Cebeco 20254	2	NL	Ar U	KM 2005	6	CZ	Bw Ra Ha HH
Cebeco 94634	6	NL	Ra	L 175-H3	2	B	Ra Ch
Cebeco 96263	2	NL	Ra Ch La	Landi	6	D	Ra
Cebeco 96643	6	NL	None	LEU 0036	6	D	Sp Bw
Cebeco 96644	6	NL	Bw	LEU 2035	6	D	IM9 Sp Ra
Cebeco 96649	6	NL	Ra HH	LEU 2039	6	D	U(E)
Cebeco 97275	2	NL	Ra	LEU 3034-1	6	D	Ru
Cebeco 99240-03	2	NL	Ly	LEU 7035	6	D	Sp Bw Ra
Cebeco 99250-11	2	NL	Ar	LEU 73121	6	D	Sp Ra
Cleopatra	2	D	Ly	LEU 93520-2	6	D	Sp Ra
CM 4110	2	B	Di La	LP 2-146	6	D	Bw
CM 13569	2	B	Ra Ch	LP 2-355	6	D	None
Cornelia	6	D	Ru	LP 2-930	2	D	Ly
CWB 98-24	2	GB	Ra	LP 2-935	2	D	Sp Ra
CWB 98-25	2	GB	Ha	LP 6-045	6	D	Ra HH
CWB 0474	2	NL	Ra Ch	LP 6-225	6	D	IM9 HH
CWB 2625/31	2	GB	Sp We	LP 6-234	6	D	IM9 Sp Bw Ra
DSV 446/96	2	D	Ar Ra	LP 6-543	6	D	U Ra
DSV 794/96	2	D	Ar Ra	LP 6-627	6	D	U
Esterel	6	F	Ra Ch	LP 6-652	6	D	Ra
GW 1869	2	D	U	LP 6-756	6	D	Ra
GW 2092	6	D	U	LP 6-763	6	D	Sp Ra
Helga	6	A	None	LP 6-857	6	D	Bw Ha HH

Table 1 continued

Variety	R	C	Resistance	Variety	R	C	Resistance
LP 896518	2	D	None	SG-C 230	2	CZ	H (Ly,Ra+ HH,Ra)
Ludo	2	DK	Ly U	SG-C 333	2	CZ	Ly
Lupida	6	D	Ra Dr	SG-C 483	2	CZ	Ra
Mathias	6	F	Ra Ch	SG-C 669	2	CZ	Ch
Menhir	2	D	Ra Ch	SG-C 695	2	CZ	Ra HH U
MH-88-ES-2.5	6	F	HH	SG-C 711	2	CZ	Ra Ch
ML-SL-130	2	CZ	None	SG-C 724	2	CZ	Ra U
NIC-90-1250	6	D	Sp Ra	SG-C 804	2	CZ	Ra Ch
NORD 20514/2	6	D	HH	SG-L 76	6	CZ	Bw Ra
NORD 20629/13	6	D	U(E)	SG-L 92/A/99	6	CZ	Bw Ra Ha HH
NORD 96515/26	6	D	U(E)	SG-L 106/01	6	CZ	Ra Ha HH
NORD 98554/17	2	D	Di	SG-L 108	6	CZ	Ra
NORD 98557/16	2	D	Di	SG-L 111	6	CZ	Bw Ra
NORD 99565/16	6	D	Sp Ra	SG-L 111/A	6	CZ	Bw Ra
NSL 96-7244	2	GB	We	SG-L 113	6	CZ	Bw Ra
NSL 97-6016	2	GB	None	SG-L 125	6	CZ	Bw Ra
NSL 97-6661	2	GB	Ly	SG-L 128/A/01	6	CZ	Bw Ra Ha HH
NSL 97-7331	2	F	Ha Ra	SG-L 546/B/99	6	CZ	Bw Ra HH
NSL 98-6213	2	GB	We U	SG-L 791/98	6	CZ	Bw Ra
NSL 99-6738	2	F	We Ha	SG-L 1010/00	6	CZ	Ra HH
NSL 99-8088	2	GB	H (Ha,Sp+Ha)	SG-L 1195/02	6	CZ	Bw Ra Ha HH
P 3712	6	A	Ra Ch Ha	SG-L 1236/C/01	6	CZ	Bw Ra Ha
P 6110.90	2	A	Ra	SG-L 1258/A/02	6	CZ	Ra HH Lu
P 7448	6	A	Ru U	SG-L 3423/A/03	6	CZ	Bw Ra HH
Palinka	6	A	Ra Ha	Siberia	6	F	Ra Ha
Petra	6	A	Ra	SL 112/86-2B	2	A	Ly
PRO 2 WB 0020	2	F	Ar	Sokol	6	PL	U
PRO 2 WB 9765	2	F	Bw Ra	STRG 326-94	6	D	Sp
PRO 2 WB 9862	2	F	Sp	STRG 782.99	2	D	Sp We Ha Dt
Rafiki	2	DK	Ra Ch	SUR.01/3128	6	D	U(E)
Regina	2	D	Ly	SW 17592	6	SE	Sp
S 7889	2	F	Bw Ra	SZD 80/95-9	6	A	Ra
Sarah	6	D	Ru	SZD 1718	6	A	Bw HH
SECO-D447-14AB	2	D	Ra Ha	SZD 2017	6	A	IM9 Sp Ra
SECO-D5572-AC	6	D	Sp Bw Ra Ha	SZD 2045	6	A	IM9 Sp Ra
Seduction	2	F	Ha Ra	SZD 7215B	6	A	Ru Ha
SG-C 80	2	CZ	Ra	Tulip	2	F	We
SG-C 90	2	CZ	Ra	Vanessa	2	D	St Ha
SG-C 105	2	CZ	H (Ly,Ra+Ra)	Venezia	2	D	U(E)
SG-C 155	2	CZ	We U				

[1]R = Kernel row type; [2]C = Country of origin (A = Austria, B = Belgium, CZ = Czech Republic, D = Germany, DK = Denmark, F = France, GB = Great Britain, NL = the Netherlands, PL = Poland and SE = Sweden); [3]Boesen *et al.* (1996); H = Heterogeneous, composed of two or more lines with different resistances to powdery mildew

ficial Trials and to compare their resistance with the resistance of spring varieties, resistance of Czech varieties with foreign ones, and resistance of two- and six-rowed varieties.

MATERIAL AND METHODS

Barley germplasm

One hundred and sixty-seven winter barley varieties included in the Czech Official Trials in 1996–2005 and those that have not been registered yet were studied. The seed of all varieties was provided by respective breeders.

Pathogen isolates

Sixteen pathotypes of *Bgh* held in the genebank at the Agricultural Research Institute in Kroměříž were used for the inoculation of tested varieties till 2001 and 30–32 pathotypes in the following four years. Between the tests in individual years, several pathotypes were always replaced by new ones with greater resolving power. Before inoculation, each pathotype was purified, verified for the correct virulence phenotype on differential hosts and increased on cultivars Pallas or Monaco.

Methods used

For inoculation procedure, evaluation of reaction types, verification of resistance spectra and identification of resistance genes see Dreiseitl (2005b).

RESULTS

All of the 167 examined varieties and their identified resistances are listed in Table 1. After inoculation with at least one *Bgh* pathotype, the plants of six varieties exhibited different RTs, and they are always composed of two lines with different resistances to powdery mildew. Out of these six heterogeneous varieties, resistance of the corresponding lines was identified in four (KM 1428, NSL 99-8088, SG-C 105, and SG-C 230).

Table 2. Frequency of selected resistances to powdery mildew found in 167 winter barley varieties included in Czech Official Trials in 1996–2005

Resistance[1]	No. of varieties				Σ
	two-rowed		six-rowed		
	Czech	foreign	Czech	foreign	
	17	66	28	56	167
Ra	9	27	25	28	89
Bw	–	2	20	8	30
Sp	–	6	1	17	24
Ly	3	13	–	–	16
We	3	6	–	–	9
Ar	–	6	–	–	6
Ru	–	–	–	6	6
IM9	–	–	–	5	5
Di	–	3	–	–	3
La	–	3	–	–	3
St	–	1	–	–	1
Heterogeneous	2	2	2	–	6
None	2	2	–	3	7
U	7	9	–	9	25
of which U(E)	–	2	–	4	6

[1]Boesen *et al.* (1996)

Seventeen known resistances to powdery mildew (Ar, Bw, Di, Dr, Dt, Ha, HH, Ch, IM9, La, Lu, Ly, Ra, Ru, Sp, St, and We) were found in the examined set. The frequency of selected resistances is given in Table 2. The resistance Ra detected in 89 varieties dominated. The resistance Bw was found in 30 varieties, and the resistances Sp and Ly were also frequently present by contrast with less frequent resistances Ar, Ca, Di, La, Ru and We. The frequencies of resistances Dr, Ha, HH and Ch, which are also often present in winter barley varieties, could not be quantified since we were able to identify these resistances gradually during the whole examined period. The resistances Dt (STRG 782.99) and Lu (SG-L 1258/A/02) were scarce. An unknown resistance was found in 25 varieties, in six of which (Himalaya, LEU 2039, NORD 20629/13, NORD 96515/26, SUR.01/3128, and Venezia) the resistance was effective against all *Bgh* pathotypes employed [U(E)].

DISCUSSION

In 1996–2005, 167 winter barley varieties were gradually tested, among which 17 known and another unknown resistances to powdery mildew were identified. Six varieties possessing unknown [U(E)] resistances were resistant to all the employed pathotypes of the pathogen. The other identified as well as unknown resistances cannot be considered valuable regarding the development of winter barley varieties resistant to powdery mildew. The resistances Ch and Lu were characterized by Dreiseitl (2005a).

Dreiseitl (2005b) studied powdery mildew resistance in 227 Czech and Slovak breeding lines of spring barley. Among them, also 17 known resistances were found, nine of which (Ar, Di, HH, La, Ly, Ru, Sp, St, and We) were detected in the examined set of winter barley varieties. The resistances Bw, Ha and Ra are typical of winter barley varieties, and therefore it is not surprising that they were present in the set of winter barley varieties and absent in the set of spring barley varieties. The resistances Dr, Dt, Ch, IM9, and Lu have been detected in winter barley varieties only until now.

The examined set includes 122 foreign and 45 Czech varieties. All 11 resistances presented in Table 2 were found in foreign varieties, whereas only five of them in Czech varieties. At least five of the six resistances (Ar, Di, La, Ru and St), which were found in foreign varieties only, are the resistances typical of spring barley varieties and thus their presence in winter barley varieties is not an advantage of the corresponding varieties of the examined set. The resistance Sp (the resistance typical of spring barley varieties), which is abundant in foreign varieties, was detected in one Czech variety only. The resistance Bw was detected in 44% of Czech varieties and in 7% of foreign varieties. The most significant finding is the presence of resistances that are fully effective against all employed pathotypes of the pathogen [U(E)]. Such resistances were found in six foreign varieties (= 3.6% of the whole examined set) that were included in official trials during the last four years (of them three varieties were included in these trials in 2005). None of the Czech varieties exhibited U(E).

The examined set consists of 83 two-rowed and 84 six-rowed varieties. The resistance Bw was found above all in six-rowed varieties (particularly in the Czech ones) and in two two-rowed (foreign) varieties only. The resistances Ar, Di, La, Ly, St and We are typical of spring barley varieties and were found only in two-rowed varieties (five of them in foreign varieties only). In contrast, the resistances IM9 and Ru were detected in six-rowed varieties only (only in the foreign ones).

The presented results demonstrate that the number of detected genes for powdery mildew resistance (17) in the set of winter barley varieties included in Czech Official Trials is the same as that in the set of spring barley varieties (17 genes). However, the percentage of fully effective resistances found in the set of winter barley varieties (3.6%) is much lower than in the set of spring barley varieties (78%) (spring varieties were studied in the period 2001–2005, whereas winter varieties in 1996–2005). It means that 96.4% of winter barley varieties – candidates for registration in the Czech Republic (100% of the Czech ones) possess resistances whose effectiveness against the pathogen is low or none (Dreiseitl 2004). Such a situation is alarming and requires effective measures. It seems that foreign breeders realized this fact earlier and the first varieties possessing fully effective resistances are not a random result, but the beginning of a new approach to the breeding of winter barley varieties resistant to powdery mildew. One of the basic conditions of successful breeding is the exploitation of other resistances than those that have been employed in the breeding of resistant spring barley varieties.

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