Powdery Mildew Resistance of Foreign Spring Barley Varieties in Czech Official Trials

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Abstract: In 1993–2005, resistance to powdery mildew was studied in 168 foreign varieties of spring barley included in Czech Official Trials in that period. Sixteen known resistances to powdery mildew were identified (Ab, Al, Ar, HH, Kw, La, Ly, MC, Mlo, N81, Ri, Ru, Sp, St, Tu, and We). Unknown resistances were found in 32 varieties, in nine of which these resistances were effective against all used pathotypes of the pathogen. Seven varieties (= 5%) exhibited heterogeneity in the examined trait, i.e. they are composed of lines (usually of two) with different resistances to powder mildew. The resistance Mlo, which was found in 75 homogeneous varieties (= 46%), dominated in the set. The resistances Ru, We, Ar and La were frequently present. The examined set includes 53% of varieties resistant to all used indigenous pathotypes of the pathogen.

Keywords: *Blumeria graminis* f.sp. *hordei*; *Erysiphe graminis* f.sp. *hordei*; powdery mildew; *Hordeum vulgare*; spring barley; varieties; resistance

The world food production is based above all on wheat grown on the area of 214 mil. ha to be harvested, rice (151 mil. ha), and maize (142 mil. ha). Barley (*Hordeum vulgare* L.) is the fourth most frequently grown crop (56 mil. ha), when 52% of its acreage is located in Europe. It is planted on 0.24% of the world land area, 1.27% of the area in Europe and 6.34% in the Czech Republic (FAOSTAT 2001–2004).

Powdery mildew, caused by the fungus *Blumeria graminis* (DC.) Golovin ex Speer f.sp. *hordei* Em. Marchal (= *Bgh*), occurs everywhere barley is grown. However, it most often causes damage in Europe, and particularly in its north-western and central parts, where the mild and humid climate is favourable not only for parallel growing of both spring and winter types, but also it facilitates growth and development of abundant volunteer plants out of season. Continuously green assimilating barley plants provide suitable conditions for the anamorph (conidial) stage of reproduction of this biotrophic pathogen. Growing of modern tillering and short-stem varieties on a high level of nutrition has considerably affected the crop density of barley, which supports further regular incidence and harmfulness of powdery mildew.

In Czechoslovakia/Czech Republic, the breeding of barley for powdery mildew resistance started many years ago and has developed in time since then (Fadrhons 1962; Brückner 1964). Significant achievements have been acknowledged in this field, some of which have influenced the breeding of this crop in a number of European countries (Brückner 1984, 1987). After World War Two, only two foreign varieties (Elgina and Trumpf) were registered in the Czech Republic mainly due to their superior resistance to powdery mildew (Dreiseitl 2003). The milestone was the year 1996, when Ditta, Krona and Signal were registered. In 2005, the percentage of foreign cultivars

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in the registered assortment amounted to almost 40% and the percentage of the area under these cultivars exceeded 50%.

The objective of this paper was to identify specific resistances to powdery mildew possessed by foreign varieties of spring barley and to compare them with resistances in Czech and Slovak breeding lines.

MATERIAL AND METHODS

Barley germplasm

One hundred and sixty-eight foreign spring barley varieties (except the Slovak ones) included in Czech Official Trials in 1993–2005 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 inoculation of the 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 the cultivar Pallas or Monaco.

Methods used

The resistance genes in each variety were postulated on the basis of the gene for gene hypothesis by comparing their resistance spectra, based on their individual reaction types, with previously determined spectra on barley differentials possessing known resistance genes. For inoculation procedure, evaluation of reaction types and verification of resistance spectra see Dreiseitl (2005).

RESULTS

All 168 examined varieties and their identified resistances are listed in Table 1. After inoculation with at least one *Bgh* pathotype, the plants of seven varieties exhibited different RTs, it means they are composed of lines (usually of two) with different resistances to powdery mildew. Of these seven heterogeneous varieties, resistance of all corresponding lines was identified in two (Cebeco 9983 and LP 7133-5) and the resistance Ar was identified in both lines of LP 1124.8.98, however they differed in the presence/absence of another unidentified resistance. No resistance was identified in any of the corresponding lines in four varieties.

Sixteen known resistances to powdery mildew (Ab, Al, Ar, HH, Kw, La, Ly, MC, Mlo, N81, Ri, Ru, Sp, St, Tu, and We) were identified in 146 out of 161 homogeneous varieties. Their frequencies are given in Table 2. The Mlo resistance dominated in the examined set when it was detected in 75 homogeneous varieties. The resistances Ru (20), We (17), Ar (16) and La (15) were frequently present. Other five resistances (Al, St, Ri, Ly, and N81) were found in four to seven varieties. The resistances Tu, HH, MC, Ab, Sp and Kw were detected in one to two varieties. An unknown resistance was found in 15 varieties, of which in nine it was effective against all used *Bgh* pathotypes. Besides the identified resistances, unknown (unidentified) resistances were detected in other 17 varieties.

Most varieties in which the resistance Mlo was found carried additional one or more resistances. These were identified in some varieties and are presented in Table 1, however they are not included in Table 2 (similarly like the unidentified, i.e. also unknown resistances of heterogeneous breeding lines).

DISCUSSION

In 1993–2005, 168 foreign varieties of spring barley were gradually tested, among which 16 known and another unknown resistances to powdery mildew were identified. The varieties possessing the resistances Mlo, Tu and unknown, fully effective resistances [U(E)], i.e. 86 out of 161 homogeneous varieties (= 53%), were resistant to all used indigenous pathotypes of the pathogen. The other identified as well as unknown resistances cannot be considered valuable for the breeding goal, which is the development of spring barley varieties resistant to powdery mildew.

Dreiseitl (2005) studied powdery mildew resistance in 227 Czech and Slovak breeding lines of spring barley. Among them, 17 known resistances were detected, out of which 13 (Al, Ar, HH, La, Ly, Mlo, N81, Ri, Ru, Sp, St, Tu, and We) were present in both examined sets. The resistances At, Kr, *Mla21* and *Mlp1* were not found in the set of

Table 1. One hundred and sixty-eight foreign varieties of spring barley included in Czech Official Trials in 1993–2005 and their resistance to powdery mildew

Variety	Resistance[1]	Country of origin
95/132 B	U	Germany
2099 02 (Nevada)	Al	France
2145 02 (Texane)	H	France
3880 i (Scarlett)	St We	Germany
4745 c	U (E)	Germany
5509 a	U (E)	Germany
5957 X	U	France
10591 X1	Al	France
A 634	Mlo	Denmark
AC 00/758/2	Mlo	Germany
AC 2905/17 (Ditta)	We U	Germany
AC 99314/120	Ar U	Germany
Barke	Mlo	Germany
BE 4530e (Optima)	Ru La We	Germany
BIE 173-21/92	Mlo	Germany
BIE 491-35/90b	N81	Germany
BIE 27385 (Wettina)	Mlo	Germany
Br 6336a	U (E)	Germany
Br 6429f (Marnie)	U (E)	Germany
Br 7035a12	U (E)	Germany
Br 7407e1	Al La	Germany
Cebeco 0029	Mlo	The Netherlands
Cebeco 0135 (Timori)	Al La	The Netherlands
Cebeco 0142	Ar U	The Netherlands
Cebeco 0144	Ar We U	The Netherlands
Cebeco 0259	Mlo	The Netherlands
Cebeco 0260	HH U	The Netherlands
Cebeco 0367	Mlo Ar	The Netherlands
Cebeco 0374	Mlo Ly	The Netherlands
Cebeco 0421	U (E)	The Netherlands
Cebeco 0422	Mlo	The Netherlands
Cebeco 0426	Mlo	The Netherlands
Cebeco 0441	Mlo	The Netherlands
Cebeco 9079	Mlo	The Netherlands
Cebeco 9420	Mlo	The Netherlands
Cebeco 9538 (Jersey)	Mlo Ar	The Netherlands
Cebeco 9650	Al	The Netherlands
Cebeco 9981	MC U	The Netherlands
Cebeco 9982 (Ceylon)	Ru U	The Netherlands
Cebeco 9983	H (Ru,La+Ar)	The Netherlands
Celinka	Ru	France
Cellar	Mlo	France

Table 1 to be continued

Variety	Resistance	Country of origin
CM 4016	Mlo	Belgium
CSBA 3353-2-730 (Fractal)	Al	Great Britain
CSBA 3446-4	Mlo	Great Britain
CSBA 4369-5 (Biatlon)	Mlo Ar We	Great Britain
CSBA 4651-14 (Prestige)	Mlo Al	Great Britain
CSBA 5138-2	Mlo	Great Britain
CSBC 1838-30 (Topic)	Mlo Al	Great Britain
CSBC 4061-1	Mlo	Great Britain
Doyen	Ri We	France
DSV 62006	Mlo	Germany
Dynamic	Ru	France
Extract	Ru La	Great Britain
F 718	Ar U	Germany
FDO 9129-510	Ru	France
FDO 95010-515	Al La	France
FDO 95019-519	Ru	France
FDO 96022-527	Mlo	France
FDO 96074-502	St	France
GS 1850 (Faustina)	St We	Germany
Hadm 51104-99	Ly	Germany
Hadm 52559-95	Mlo	Germany
Hadm 64533-01	Mlo	Germany
Halla	Ly We U	Germany
Krona	Mlo	Germany
Lipp 90/95	Mlo	Germany
LP 2.9294 (Orthega)	Ar We La	Germany
LP 2.01168	Mlo	Germany
LP 620.3.99	Ru La	Germany
LP 697.94 (Philadelphia)	Mlo	Germany
LP 731.631	Mlo	Germany
LP 813.6.98	Ar La	Germany
LP 1008.1.98	Ar U	Germany
LP 1050.2.97	Ru La	Germany
LP 1124.8.98	H (Ar,U+Ar)	Germany
LP 1452.5.99	Ru La	Germany
LP 1506.1.96	Ri Tu	Germany
LP 7055-9	H	Germany
LP 7133-5 (Madonna)	H (Mlo+Ar)	Germany
LP 7536-32	Ar We	Germany
LP 7999-63	Mlo	Germany
LW 97 Z009.04	Mlo	The Netherlands
M 12	Mlo	Hungary
M 88/17-1	Mlo Ar	Hungary

Table 1 to be continued

Variety	Resistance	Country of origin
Margret	Sp	Germany
N 94663 D5 (Diplom)	Ar La	Germany
N 95036 D3	Ar	Germany
N 95045 D1	Mlo	Germany
NFC 401-5	Mlo Ru We	Great Britain
NFC 401-8 (Carvilla)	Mlo Ru We	Great Britain
NFC 401-11	Ri Tu	Great Britain
NFC 403-43	Mlo	Great Britain
NFC 495-17 (Sabel)	Mlo Ar We	Great Britain
NFC 496-10 (Saloon)	Mlo Ar	Great Britain
NFC 497-33 (Brise)	Mlo Ru	Great Britain
NFC 498-45 (Baemar)	Mlo Ru La	Great Britain
NFC 499-67 (Carafe)	Ru We	Great Britain
NFC 499-72 (Cocktail)	Ru U	Great Britain
NORD 00/2310	Mlo	Germany
NORD 01/2449	Ar La	Germany
NORD 01/2515	Mlo Ar We	Germany
NORD 02/2337	U (E)	Germany
NORD 02/2338	Mlo	Germany
NORD 92 K0012 D14 (Annabell)	St	Germany
NORD 92 K0015 D22	Mlo	Germany
NORD 1898 (Bolina)	St	Germany
NORD 1901 (Eurojet)	Mlo Ar	Germany
NORD 1913	N81 La	Germany
NS 90/1320 (Daniel)	Mlo	Germany
NS 90/1465 (Nordus)	Mlo	Germany
NS 96/1115	N81	Germany
NS 98/1107	St	Germany
NS 98/1112	U	Germany
NSL 00-5033	Mlo HH La	Great Britain
NSL 02-4144	Mlo	Great Britain
NSL 96-2580	Mlo	Great Britain
NSL 98-1867	Mlo Ru	Great Britain
NSL 98-1871	Mlo	Great Britain
NSL 98-4087	Mlo	Great Britain
P 6832.92	U	Austria
P 6833.92 (Prosa)	We U	Austria
PF 18147-54	U (E)	Denmark
PF 51272-6	U	Denmark
Riviera	Mlo	Great Britain
S 3482 (Calgari)	Mlo MC	France
S.010218	Ar Ab	France
SBWI-1 (SA93013)	U	Australia

Table 1 to be continued

Variety	Resistance	Country of origin
SE 268/99	Mlo	Austria
SE 321/98	Mlo	Austria
SE 93018.2	Ru We	Austria
SEMU 34186	Mlo	Germany
SEMU 80087	Ru La	Germany
SEMU 82768	Ly	Germany
SEMU 86027 (Madeira)	Mlo Ar	Germany
SEMU 96055	Ru We	Germany
SCHW 26-87	Ru	Germany
SCHW 325-93-1	N81 La	Germany
Signal	Ly U	Austria
SJ 6242	Mlo	Denmark
SJ 8029	Mlo Ar We	Denmark
SJ 027164	Mlo Ru	Denmark
SJ 032231	Ri	Denmark
SJ 203118	Ri We U	Denmark
SJ 991771 (Simba)	Mlo	Denmark
SJ 997 195 (Sebastian)	Ar Ab	Denmark
SL 39/90-14	Ru	Austria
SL 46/93C-20	U (E)	Austria
Start	We	Poland
SW 1562	Mlo	Sweden
SW 1650	Ar We U	Sweden
SW 2517	Mlo	Sweden
SW 2529	Mlo	Sweden
SW 2761	Ri Kw	Sweden
SW 2808	H	Sweden
SW 8732	HH	Sweden
Tabora	Ru	France
Thuringia	H	Germany
Tremois	Ly We U	France
UNSJ 997173 (Christina)	Ar U	Denmark
VDH 4044-87 (Riff)	Mlo	The Netherlands
VDH 4053-88 (Ragtime)	Mlo	The Netherlands
VDH 4132-87 (Reggae)	Mlo	The Netherlands
VDH 4198-91	Ru	The Netherlands
Video	Mlo	The Netherlands
Viva	MC	Austria
W 97.6 E	Mlo HH	France
Whopie	Ru	Sweden

[1]Boesen *et al.* (1996); HH = Heils Hanna; H = heterogeneous, composed of two or more lines with different resistances to powdery mildew

Table 2. Frequency of resistances to powdery mildew found in 168 foreign spring barley varieties included in Czech Official Trials in 1993–2005

Resistance		Total		Resistance		Total	
Code[1]	Gene	1993–2005	2001–2005	Code	Gene	1993–2005	2001–2005
Mlo	*mlo*	75+1	41	Tu	*Ml(Tu2)*	2	1
Ru	*Mla13*	20+1	9	HH	*Mla8*	2	1
We	*Mlg*	17	4	MC	*Mla9*	2	1
Ar	*Mla12*	16+2	11	Ab	*Ml(Ab)*	2	2
La	*MlLa*	15+1	10	Sp	*Mla6*	1	1
Al	*Mla1*	7	4	Kw	*Mlk1*	1	1
St	*Ml(St)*	6	2	U	unknown	6	3
Ri	*Mla3*	6	5	U+	unknown	17	11
Ly	*Mla7*	5	1	U(E)	unknown	9	7
N81	*Ml(N81)*	4	2				

[1]Boesen *et al.* (1996); if the symbol "+" is in a column, the frequency of corresponding resistance found in homogeneous varieties is given first followed by the frequency of the given resistance in heterogeneous varieties

foreign varieties, whereas the resistances Ab, Kw and MC were not found in the set of Czech and Slovak breeding lines. In both sets, however, the frequency of these seven resistances was very low (each of them was present at most in two varieties of the corresponding set).

The presented results demonstrate that the number of resistances detected in the two compared sets is similar and the effectiveness of five out of the seven known, mutually different resistances is comparable (insignificant). The resistances Kw and MC that were not detected in Czech and Slovak breeding lines (Dreiseitl 2005) are common in older cultivars (Dreiseitl & Jørgensen 2000). The resistances *Mla21* and *Mlp1*, found in the current set of Czech and Slovak breeding lines, are fully effective and could be identified on the basis of knowledge of pedigrees of the respective breeding lines only. Without such information, they would be included in the group of unknown, fully effective resistances [U(E)].

The resistance N81, possessed by Czech and Slovak varieties (Dreiseitl & Jørgensen 2000; Dreiseitl 2005), is derived from the landrace Nepal 81 (Brückner 1986). Using the given pathotypes, the identical resistance spectrum was assessed for some foreign varieties, including Signal, and therefore their resistance was identified as N81. Studying the pathogen population, the two varieties (Nepal 81 and Signal) were included in the differentiation set. Some pathotypes differing in virulence/avirulence to these varieties were found (Dreiseitl unpublished). It seems that the resistance of varieties, which is designated N81 in this paper, can contain two different resistances.

The current set consists of 53% of homogeneous foreign varieties with fully effective resistances (46% of them contain the resistance Mlo), whereas the set of Czech and Slovak breeding lines (Dreiseitl 2005) includes 78% with fully effective resistance (72% of them contain the resistance Mlo). The two compared sets differ above all in the percentage of heterogeneous varieties. Their proportions were 5 and 29% in the foreign varieties and Czech and Slovak breeding lines, respectively (for instance, the proportion in Latvian cultivars was up to 53% (Dreiseitl & Rashal 2004)).

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