Variety Resistance of Winter Barley to Powdery Mildew in the Field in 1976–2005

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Abstract: The results of evaluation of powdery mildew resistance in winter barley varieties in 285 Czech Official Trials conducted at 20 locations were analysed. Over the period, the number of varieties tested per year increased from four to seven in 1976–1985 to 53–61 in 2002–2005. To assess the resistance of varieties, only trials with sufficient disease severity were used. In 1976–2000, six varieties (1.7% of the varieties tested in the given years) ranked among resistant (average resistance of a variety in a year > 7.5) including NR-468 possessing the gene *Mla13*, KM-2099 with *mlo* and Marinka with the genes *Mla7*, *MlaMu2*. In 2001–2005, already 33 varieties (16.9%) ranked among resistant, of which Traminer possessing the genes *Ml(St)* and *Ml(IM9)* dominated. The proportion of susceptible varieties (average resistance ≤ 5.5) did not change in the two mentioned periods. Two-rowed varieties began to be tested as late as in 1990 (the first variety was Danilo), however, no difference was found in the resistance of two- and six-rowed varieties. Using an example of two pairs of varieties (Dura-Miraj and Marinka-Tiffany) with identical genes for specific resistance but with different resistance in the field, the efficiency of non-specific resistance is discussed. The resistance of domestic and foreign varieties was similar in 1994–2000; however, in 2001–2005 the difference was 0.75 point to disadvantage of domestic ones.

Keywords: *Blumeria graminis* f.sp. *hordei*; *Erysiphe graminis* f.sp. *hordei*; *Hordeum vulgare*; non-specific resistance; specific resistance

Winter barley (*Hordeum vulgare* L.) is infected by more diseases than spring barley. Nevertheless, powdery mildew caused by the ascomycete *Blumeria graminis* DC. f.sp. *hordei* Ém. Marchal is the most frequent disease on this crop (Dreiseitl & Jurečka 1997; Dreiseitl 2003a). During the process of barley breeding, testing and growing, a high priority has been attributed to resistance to this disease – in spring barley for several decades and in winter barley particularly in recent years. The level of powdery mildew resistance annually ranks among a few observed agronomic traits of each barley variety.

The current national research programme is focused on problems of powdery mildew resistance in barley and conducted in several major directions. One of them is the study of barley germplasm aiming to detect new resistance resources and their genetic backgrounds (Dreiseitl & Bockelman 2003; Dreiseitl & Dinoor 2004; Řepková *et al*. 2006; Dreiseitl & Yang 2007; Dreiseitl *et al.* 2007). Breeders of spring barley use particularly the gene *mlo* to achieve resistance in new varieties. Therefore, new efficient resistance resources should be used for breeding resistant varieties to reduce the damage of winter barley and transmission of the pathogen to spring barley.

The objective of this paper was to evaluate powdery mildew resistance in winter barley in the field and the development of this trait in varieties taken into consideration for growing in the Czech Republic using an approach similar to that in spring barley (Dreiseitl & Paříze k 2003).

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MATERIAL AND METHODS

The results of evaluation of powdery mildew resistance in winter barley varieties in field trials of the Central Institute for Supervising and Testing in Agriculture of the Czech Republic conducted at 20 locations in 1976–2005 (harvest years) were analysed.

Trials. During the period studied, 285 Czech Official Trials were analysed. The trials where no variety was scored ≤ 6 are considered as the trials with insufficient disease severity and they were excluded from further evaluation (130 trials). The trials exhibiting the mean of variety infection/resistance of ≤ 6 are considered as the trials with high disease severity (57 trials). The trials where at least one variety was scored ≤ 6, but do not reach the parameter of the previous category, are considered as the trials with low disease severity (98 trials). Both categories are considered as the trials with sufficient severity of the disease investigated (155 trials) (for details see Dreiseitl 2007b).

Varieties. Two hundred and forty varieties (including the check ones) tested in the Czech Official Trials, for which data from all locations in a given crop season were available, were analysed (commercial names of registered varieties are also used in the years before their registration).

Scoring scale. A 1–9 scale was used for scoring resistance of varieties where 1 = highly susceptible variety (extreme infection of whole plants by powdery mildew) and 9 = fully resistant variety (plants are without visible symptoms of powdery mildew infection). A total of 4376 data on the resistance of the examined varieties were analysed, out of which 607 assessments were exploited in this study (assessment = average resistance of a variety in a year) (Table 1, for details see Dreiseitl 2007b).

Scoring procedure. In 1976–1988, the resistance of each variety at a given location was a result of one scoring. Since 1989, all plots (in two to four replications) have been scored, and the resistance of each variety is a mean of the scoring of a corresponding number of replications. The varieties with average resistance of > 7.5 points are considered resistant and those with average resistance of < 5.5 susceptible. The scoring of the variety-location being ≤ 4 points is considered as very low resistance (= high susceptibility). To judge the resistance of the varieties, only data from the trials with sufficient disease severity (Tables 1 and 3) and/or data of the trials with high disease severity (Tables 2 and 4) were used.

RESULTS

In two years (1979 and 1982), the resistance of examined varieties was not scored since sufficient disease severity was not recorded at any location. In 2002, the evaluation of 25 varieties is missing (Table 1). Thus, 607 assessments were analysed, out of which 114 (18.8%) corresponded to an average resistance score of ≤ 5.5 (susceptible variety) and 82 (13.5%) to an average resistance score of > 7.5 (resistant variety). In 2003, the resistance was scored at one location only because the other trials were damaged by severe frosts.

Thirty-nine varieties (= 16.2% of the total number of 240) exhibited, in trials with high disease severity, an average resistance score of > 7.5 (resistant varieties) at least in one year (Table 2). There were other seven varieties that did not reach such resistance, however, they were the most resistant of all examined varieties in a given year. The variety Traminer was assessed resistant four times in five years. Also, Erfa and Agrilo ranked among resistant varieties. However, they were included in a susceptible group in other years. In 1976–2000, six varieties were found resistant which account for 1.7% of the total number of 360 assessments for the given period (Table 1), whereas in 2001–2005, 41 resistance assessments were found for 33 resistant varieties (= 16.9% of 247).

For 97 varieties 226 data demonstrating high susceptibility (scores of ≤ 4), and mainly 73 for two-rowed (however, they started testing as late as in 1990, and the first of them was the variety Danilo) and 153 for six-rowed varieties were found (Table 3). The highest number of such data was found in foreign six-rowed varieties, Sigra (16) and Erfa (11) (however, Erfa was one of two varieties with the longest testing period). The foreign six-rowed varieties Bollo and Polaris were tested in 1976 only; in spite of that, four data of high susceptibility were found for each of them.

Spike type (*i.e.* the number of rows in spikes) has been recorded since 1994, which enabled to analyse the resistance in relation to this character (Table 4). Out of 433 assessments analysed in 1994–2005, 211 were two-rowed varieties and 222 were six-rowed varieties. The means of resistance scores in both these sets were similar (5.18 and 5.25). Within annual means, the largest difference

Table 1. Numbers of winter barley varieties in the Czech Official Trials in 1976–2005 and their grouping based on powdery mildew resistance in trials with sufficient disease severity

Year	No. of varieties	Average variety resistance[a]										
		susceptible				moderately resistant				resistant		
		≤ 4.0	4.5	5.0	5.5	6.0	6.5	7.0	7.5	8.0	8.5	9.0
1976	7		2	1			2	1		1		
1977	5			1				1	1	2		
1978	5					3		1		1		
1979	[b]6											
1980	5				3	1		1				
1981	4					1	2	1				
1982	[b]4											
1983	5			1	1	1		1			1	
1984	6				1	2	1		1	1		
1985	7					1		2	3	1		
1986	8					1	2	5				
1987	10						2	6	2			
1988	9		1		2	3	3					
1989	10					1	5	4				
1990	11					6	4		1			
1991	11						2	5	1	2	1	
1992	12					2	4	3	2	1		
1993	16				2	5	5	2	1		1	
1994	16					1	2	2	8	3		
1995	17		4	5	5	3						
1996	25			1		3	5	12	3	1		
1997	38					6	9	7	15	1		
1998	43					3	1	4	6	9	11	9
1999	46	7	4	13	9	6	4	1	2			
2000	44			1	3	14	8	13	2	2	1	
2001	46			3	8	19	6	6	3	1		
2002	[c]55		1		3	4	6	7	4	3	2	
2003	53	8	5		4	6	7	7	4	12		
2004	57				4	5	11	13	20	4		
2005	61			3	8	13	7	12	7	8	1	2
Sum I	642	15	17	29	53	110	98	117	86	53	18	11
Sum II	607	114				411				82		

[a]1–9 scale was used for scoring the resistance of varieties where 9 = fully resistant variety (plants are without visible symptoms of powdery mildew infection); [b]sufficient disease severity was not recorded at any location; [c]scoring of 25 varieties is missing

Table 2. The most resistant varieties in the Czech Official Trials with high powdery mildew severity (those with average resistant score of > 7.5 in bold)

Year	Variety	Spike type	Average variety resistance	Year	Variety	Spike type	Average variety resistance
1976	**Erfa**	**6**	[a]**7.8**	2003	**SUR.965936**	**6**	**7.7**
1977	–			2003	**NORD 96515/26**	**6**	**7.7**
1978	–			2003	**P 3712**	**6**	**7.7**
1979	–			2003	**SZD 7215B**	**6**	**7.7**
1980	–			2003	**SUR.01/3128**	**6**	**7.7**
1981	–			2003	**Cebeco 99250-11**	**2**	**7.7**
1982	–			2003	**Cebeco 98208-12**	**2**	**7.7**
1983	**NR-468**	**6**	**8.3**	2003	**NSL 98-6213**	**2**	**7.7**
1984	NR-468	6	7.2	2004	**Traminer**	**6**	**8.0**
1985	HVW 247	6	7.0	2004	**SUR.01/3128**	**6**	**8.0**
1986	KM-67[b]	6	6.5	2004	**NORD 96515/26**	**6**	**7.7**
1987	HVW 342	6	6.0	2004	**Graciosa**	**2**	**7.7**
1988	Borwina	6	6.0	2004	**Merlot**	**6**	**7.7**
1989	Sorna	6	5.5	2004	**SG-C 155**[b]	**2**	**7.7**
1990	Marinka	2	7.3	2004	**Venezia**	**2**	**7.7**
1991	**KM-2099**[b]	**6**	**8.0**	2004	**370-BC**	**6**	**7.7**
1991	**Marinka**	**2**	**8.0**	2004	**SG-C 804**[a]	2	**7.7**
1992	KM-2099[b]	6	7.2	2004	**SECO-D 447-14AB**	**2**	**7.7**
1993	KM-2099[b]	6	7.4	2004	**NSL 97-7331**	**2**	**7.7**
1994	**Agrilo**	**2**	**7.8**	2004	**Angela**	**6**	**7.7**
1995	LP 2146	6	5.8	2004	**DSV 446/96**	**2**	**7.7**
1996	Marinka	2	6.3	2005	**NORD 20629/13**	**6**	**8.0**
1997	NIC-90-1250	6	5.5	2005	**SUR.01/3128**	**6**	**8.0**
1998	–			2005	**LEU 2039**	**6**	**8.0**
1999	Carola	6	6.3	2005	**SG-L 1258/A/02**[b]	**6**	**8.0**
2000	**Carola**	**6**	**8.2**	2005	**Traminer**	**6**	**8.0**
2001	**GW 2092**	**6**	**8.5**	2005	**CM4110**	**2**	**8.0**
2001	**Traminer**	**6**	**8.4**	2005	**LEU 0036**	**6**	**8.0**
2001	**Duet**	**2**	**7.8**	2005	**SZD 2045**	**6**	**8.0**
2002	Carola	6	7.3	2005	**NORD 98557/16**	**2**	**8.0**
2003	**Traminer**	**6**	**8.0**	2005	**NORD 20514/2**	**6**	**8.0**
2003	**NORD 98557/16**	**2**	**8.0**	2005	**STRG 782.99**	**2**	**8.0**
2003	**Venezia**	**2**	**8.0**	2005	**Seduction**	**2**	**8.0**
2003	**Gilberta**	**6**	**7.7**	2005	**SG-L 106/01**[a]	**6**	**7.7**

[a]1–9 scale was used for scoring the resistance of varieties where 9 = fully resistant variety (plants are without visible symptoms of powdery mildew infection); [b]Czech varieties; – no data due to low disease severity (1978, 1979, 1982 and 1998) or a low number of varieties (1977, 1980 and 1981)

Table 3. A list of 97 winter barley varieties tested in the Czech Official Trials in 1976–2005 whose resistance score was ≤ 4 (susceptibility) at least at one location and in one year

Variety	Spike type	No. of data ≤ 4[a]	No. of test years of variety	Variety	Spike type	No. of data ≤ 4	No. of test years of variety
Agrilo	2	4	7	LU-9[b]	6	2	3
Alissa	6	4	8	LU-20[b]	6	4	3
Angela	6	1	7	LU-45[b]	6	2	3
Angora	2	1	4	Ludo	2	1	1
Astrid	2	2	3	**Lunet**[b]	6	5	13
Ayla	2	1	2	**Lupida**	6	1	3
Babylone	2	2	7	**Luran**[b]	6	3	10
BE 141601	6	1	1	**Luxor**[b]	6	4	13
Bollo	6	4	1	Marinka	2	2	10
Borwina	6	6	12	**Marna**	2	5	7
BR 2611m	2	1	2	Mascara	2	1	4
Camera	2	2	8	Mathias	6	5	3
Campill	6	3	5	**MH 88 ES 2.5**	6	5	3
Cebeco 03257-0202	2	1	1	ML-SL-130	2	1	1
Cebeco 20254	2	1	1	**Monaco**	2	6	9
Cebeco 96263	2	1	3	Nebelia	6	4	3
Cebeco 96644	6	4	3	Nelly	6	1	8
CWB 0474	2	1	1	Nives	6	1	5
CWB 2625/31	2	1	3	NSL 97-6661	2	2	2
Danilo	2	2	2	NSL 97-7331	2	1	4
Dilana	6	1	1	**Okal**[b]	6	6	14
Dura	6	2	3	P 7448	6	1	1
Erfa	6	11	13	Pastoral	2	1	1
Ermo	6	2	2	Petra	6	1	1
Helga	6	1	1	**Polaris**	6	4	1
HM-403[b]	6	1	1	Regina	2	1	4
HM-405[b]	6	1	1	**Reni**	2	4	7
HM-407[b]	6	1	1	Sarah	6	1	3
HVW 0024/78	6	2	1	SECO-D 447-14AB	2	1	2
HVW 1064	6	2	2	SG-C 230[b]	2	1	1
HVW 1066	6	2	3	**SG-C 333**[b]	2	1	1
Intro	2	1	3	SG-C 483[b]	2	1	1
Jolante	2	4	9	**SG-C 669**[b]	2	4	3
Kamil[b]	6	5	10	SG-C 804[b]	2	1	4
Kiruna	6	1	6	SG-L 74[b]	6	1	3
KM-67[b]	6	2	4	SG-L 113[b]	6	1	2
KM-103[b]	2	1	1	**SG-L 128/A/01**[b]	6	1	3
KM-237[b]	6	1	3	SG-L 459[b]	6	1	2

Table 3 continued

Variety	Spike type	No. of data ≤ 4[a]	No. of test years of variety	Variety	Spike type	No. of data ≤ 4	No. of test years of variety
KM-906[b]	6	1	1	SG-L 546/B/99[b]	6	1	1
KM-948[b]	6	1	3	SG-L 3423/A/03[b]	6	1	1
KM-1428[b]	6	1	1	**Siberia**	6	1	2
Kompolti Korai	6	1	1	**Sigra**	6	16	8
Kromir[b]	6	2	9	Silke	6	3	6
Kromoz[b]	6	3	12	SL 112/86-2B	2	1	3
LEU 7035	6	1	1	Sorna	6	3	4
LEU 73121	6	1	1	**Tiffany**	2	6	10
Lomerit	6	4	7	Vanessa	2	2	5
LP 6-756	6	1	1	Vilna	2	3	8
LP 896518	2	1	1	Sum		226	

[a]1–9 scale was used for scoring the resistance of varieties where 9 = fully resistant variety (plants are without visible symptoms of powdery mildew infection); [b]Czech varieties; the varieties in bold were the most susceptible at least in one year

in resistance between two- and six-rowed varieties was found in 2004 (0.51 point) and the smallest one in 1997 (0.01).

Two-rowed domestic varieties were represented by 23 assessments (mean 4.90) only, of which the varieties tested in 1994–2000 by five assessments (mean 4.40) and the varieties tested in 2001–2005 by 18 assessments (mean 5.04). Two-rowed foreign varieties were represented by 188 assessments (mean 5.21), of which the varieties tested in 1994–2000 by 80 assessments (mean 4.40) and the varieties tested in 2001–2005 by 108 assessments (mean 5.81).

Six-rowed domestic varieties were represented by 82 assessments (mean 4.71), of which the varieties tested in 1994–2000 by 59 assessments (mean 4.50) and the varieties tested in 2001–2005 by 23 assessments (mean 5.25). Six-rowed foreign varieties were represented by 140 assessments (mean 5.57), of which the varieties tested in 1994–2000 by 42 assessments (mean 4.51) and the varieties tested in 2001–2005 by 98 assessments (mean 6.03).

The resistance of two-rowed domestic and two-rowed foreign varieties tested in 1994–2000 was identical (4.40), whereas the difference in the resistance was 0.77 for the varieties tested in 2001–2005. Likewise, the difference in the resistance of six-rowed domestic and six-rowed foreign varieties tested in 1994–2000 was negligible (0.01), whereas it was 0.78 for the varieties tested in 2001–2005.

All domestic varieties were represented by 105 assessments at average resistance of 4.75, of which the varieties tested in 1994–2000 by 64 assessments (mean 4.50), and the varieties tested in 2001–2005 by 41 assessments (mean 5.16). All foreign varieties were represented by 328 assessments at average resistance of 5.37, of which the varieties tested in 1994–2000 by 122 assessments (mean 4.44) and the varieties tested in 2001–2005 by 206 assessments (mean 5.91).

The difference in average resistance of all domestic and all foreign varieties was 0.62, of which this difference was negligible (0.06) in the varieties tested in 1994–2000, whereas it was 0.75 in the varieties tested in 2001–2005. Resistance of domestic two-rowed varieties increased by 0.64 in the period 2001–2005 in comparison with 1994–2000, and resistance of domestic six-rowed varieties increased by 0.75, whereas resistance of foreign two-rowed varieties increased by 1.41 and foreign six-rowed varieties by 1.52.

DISCUSSION

The resistance of a variety to a disease is controlled by genes of specific resistance and genetic background. The efficiency of specific-resistance genes depends on the frequency of matching virulences in the pathogen population. The genetic background of the variety results in a certain level

Table 4. Numbers of winter barley varieties in the Czech Official Trials in 1994–2005, their grouping according to spike type and origin, and their average resistance to powdery mildew in trials with high disease severity

Year	No. of two-rowed varieties	Average variety resistance	No. of six-rowed varieties	Average variety resistance	No. of all varieties	Average variety resistance
1994	7	[a]5.71	9	5.58	16	5.64
1995	8	5.74	9	6.02	17	5.89
1996	12	4.09	13	4.34	25	4.22
1997	16	4.63	22	4.64	38	4.63
1998	–	–	–	–	–	–
1999	20	2.56	26	3.05	46	2.84
2000	22	5.18	22	5.15	44	5.16
2001	23	5.52	23	6.01	46	5.77
2002	14	5.49	16	5.16	30	5.31
2003	28	6.25	25	5.84	53	6.06
2004	31	5.67	26	6.18	57	5.90
2005	30	5.47	31	5.93	61	5.70
Sum/mean	211	5.18	222	5.25	433	5.22
Varieties according to the origin:						
Domestic (all)	23	4.90	82	4.71	105	4.75
1994–2000	5	4.40	59	4.50	64	4.50
2001–2005	18	5.04	23	5.25	41	5.16
Foreign (all)	188	5.21	140	5.57	328	5.37
1994–2000	80	4.40	42	4.51	122	4.44
2001–2005	108	5.81	98	6.03	206	5.91

[a]1–9 scale was used for scoring the resistance of varieties where 9 = fully resistant variety (plants are without visible symptoms of powdery mildew infection); – not evaluated, high disease severity was not recorded at any location in 1998

of quantitative (non-specific) resistance that depends on the actual composition of the pathogen population to a lesser extent. The proportion of resistant/susceptible varieties affects the level of an inoculation potential of the pathogen at a given location and, reversely, also the level of the resistance/susceptibility of varieties. Likewise, specific environmental conditions of the given year at the given location can result generally or specifically in a low or zero inoculation potential of the pathogen, and all tested varieties look like resistant. Therefore, the results of trials with sufficient and/or high disease severity were used to judge the resistance of varieties.

In spite of this approach (*i.e.* elimination of trials with insufficient disease severity), in some cases sets of similar varieties were included in considerably different categories of resistance, just due to the distinct actual disease severity. The year 1995 is an example, when 16 varieties were tested, out of which 14 were also tested in the previous year 1994. The year 1995 was atypical by very different infection of varieties at various locations when four out of six trials exhibited insufficient disease severity (and their results were not used for the evaluation of resistance) in contrast to the remaining two trials that exhibited very high disease severity (the highest one for the whole period studied, see Dreiseitl 2007b) although both sets of varieties in 1994 and 1995 were almost identical. However, the evaluation of these varieties considerably differed from that in the preceding year 1994 due to different disease severity (Table 1), similarly like the means of resistance of 14 varieties that were identical in both years (7.0 and 4.9 points in 1994 and 1995, respectively).

To evaluate the most resistant varieties (Table 2), only the data from trials (locations) with high disease severity were used in order to reduce a seasonal effect. It enabled to increase variety differences. However, the results of only 20% of the total number of conducted trials were used, so the resistance of the varieties in four years (1978, 1979, 1982 and 1998) could not be evaluated because high disease severity was not found at any location in these years. In another 11 years, the variety characterisation is based on the evaluation of resistance at one location only. Results from these years fully depended on one evaluator. However, some surprising results were found even in years with a sufficient number of trials with high disease severity. For instance, the variety Erfa carries the resistance gene *Mla8* (Dreiseitl 2007a). This gene was also detected in some most susceptible barley varieties e.g. Diamant (Dreiseitl & Jørgensen 2000), Pallas (Køl-ster *et al.* 1986), Golden Promise and SM-4142 (Dreiseitl unpublished), and it is of no practical importance because the European population of the pathogen is characterised by 100% frequency of matching virulences (Hovmøller *et al.* 2000; Dreiseitl 2004). Despite that, Erfa was included in the category "resistant" (the year 1976 belonged to the seasons with the highest disease severity!). Erfa was tested up to 1989 (except of 1977) and mostly ranked among susceptible varieties, which is documented by its second place among 240 varieties (following the variety Sigra) with the largest number of data of high susceptibility (Table 3). Therefore, the inclusion of this variety in the trials with high disease severity in the category "resistant" in 1976 is surprising and could have been caused by an undetectable error.

On the contrary, in 1983 the variety NR-468 was included among resistant ones. It corresponds to its genetic basis of resistance, the gene *Mla13* (Dreiseitl 2007a). Average resistance of NR-468 in trials with high disease severity was 8.3 (mean of three trials) in 1983, and thus it was far from the rest of the varieties examined in that year. In 1984, however, it exhibited the resistance of "only" 7.2 (mean of four trials). It is again quite a surprising, but remarkable finding. The gene *Mla13* ranks among the most important genes because it was used above all in numerous Czech and Slovak spring barley varieties (Dreiseitl & Jørgensen 2000) that were planted on more than 50% of the area under this crop in the Czech Republic in 1983–1991 (Dreiseitl 1993). The year 1985 is considered as the year of breaking down the resistance conferred by this gene because in 1984 the barley varieties Koral, Krystal and Zenit still exhibited the high average resistance of 8.80–9.00 in trials with high disease severity (Dreiseitl 2003b), and a decrease in the resistance of spring barley varieties with this gene was recorded at some locations as late as in 1985 (Dreiseitl & Jurečka 2003). However, the present results document that the winter barley variety NR-468 showed reduced resistance conferred by the gene *Mla13* already in 1984, *i.e.* one year earlier than a similar decrease was found in spring barley varieties. Nevertheless, on the average of three out of eight registration trials, at Lípa, Kujavy and Libějovice locations, the resistance of the variety NR-468 was scored 6.7, which is even lower resistance than that of the variety Sigra (7.3), which had the highest number of scores of high susceptibility during its testing (Table 3). Dreiseitl and Jurečka (2003) were of the opinion that one of the reasons for overcoming the efficiency of the gene *Mla13* had been a dramatic enlargement of the area under winter barley. In winter varieties, directional selection of virulent pathotypes takes more time than in spring varieties, which enables to reach a higher level of the disease caused by rare virulent pathotypes by then, and thus to produce a much richer population of virulent individuals.

KM-2099 was another variety that ranked among resistant varieties as late as after eight years (1991). It is the only known variety of winter barley in which the gene of non-host resistance *mlo* was found (Dreiseitl & Jørgensen 2000). This finding was firstly presented to the 8th Cereal Rusts and Mildews Conference (Weihenstephan, Germany, 1992) and attracted a great attention. The identification of the gene *mlo* in a variety of winter barley (Dreiseitl 1995) in connection with a general opinion that this gene is attributed to spring barley varieties only could be one of the reasons why KM-2099 was not registered. The decrease in KM-2099 resistance in the very next year 1984 could be caused by a stress when some disease symptoms can occur on varieties possessing the gene *mlo* or, maybe, by an admixture of the seed of less resistant varieties, but not by a permanent decrease in the efficiency because the resistance of varieties with this gene is most frequently scored 9 even after more than 20 years.

Likewise, the variety Marinka, which was tested since 1990, made a progress in powdery mildew resistance in winter barley. However, it carries

the genes *Mla7* and *MlaMu2* (Dreiseitl 2007a), for which a high proportion of pathotypes of the given pathogen occurred at this time (Dreiseitl & Schwarzbach 1994). The identical genes of specific resistance possessed by Marinka are also present in the variety Tiffany (Dreiseitl 2007a). In all four years of common testing (1996–1999), Marinka was more resistant, on average by 0.91 point, which probably reflects a higher level of its non-specific resistance.

In 1976, Bollo and Polaris were the most susceptible varieties, which could even be the most susceptible varieties for the whole period examined. After their removal, in 1977 Dura became the most susceptible variety exhibiting higher susceptibility (by 2.33 points) than the second susceptible variety in that year, Miraj. This difference shifted the variety Dura away from the rest of the actual set of varieties for the whole period (Table 1). The varieties Dura and Miraj carry identical genes of specific resistance *Mlra* and *Ml(Du2)* (Dreiseitl 2007a). However, on the average of three years of common testing (1976–1978), average resistance of Miraj was by 1.78 higher than the resistance of the variety Dura. It is obviously an evidence of a greater difference in the level of their non-specific resistance than that in the earlier mentioned varieties, Marinka and Tiffany.

The variety Agrilo, which was included among resistant varieties in trials with high disease severity in 1994, can be characterised similarly like the variety Erfa, in which the genes *Mlra* and *Ml*(*Dr2*) were found. These genes are of negligible practical importance (Hovmøller *et al.* 2000; Dreiseitl 2004), and the variety Agrilo showed repeatedly high susceptibility (Table 3). Another resistant variety, Carola, was the first tested variety in the Czech Republic possessing the gene *Ml(St)* in addition to other insignificant resistance genes (Dreiseitl 2007a). However, varieties with this gene had been grown earlier in some other European countries, therefore in 2004 the frequency of virulences to resistance genes of the variety Carola accounted for 14.1% (Dreiseitl 2004). A lower frequency of virulences to resistance genes of the variety Carola enabled to include it among resistant varieties in years with low disease severity (*e.g.* in 2000), however, in years with high disease severity, the variety Carola did not fall among resistant ones (*e.g.* in 1999).

In 2001, Traminer possessing the genes *Ml(St)* and *Ml(IM9)* started testing. The variety ranked among resistant varieties in that and subsequent years. However in 2002, in the only trial with high disease severity, it was scored 7 only (the difference in scoring was probably caused by a subjective error because Traminer carries the identical resistance gene as the variety Carola, but in addition, it has another efficient gene; so the resistance of Traminer should be higher than that of Carola, which was scored 7.3).

In 2001 (*i.e.* in the year when the tests of the variety Traminer started), resistant varieties began to occur frequently. These were particularly varieties with fully efficient unknown (unidentified) resistance genes designated U(E), such as LEU 2039, NORD 96515/26, NORD 20629/13, SUR01/3128 and Venezia, as well as varieties with resistance genes that (similarly like in the discussed varieties Erfa and Agrilo) question their inclusion them among resistant ones (*e.g.* P 3712, Cebeco 99250-11, Premuda and some others) (Dreiseitl 2005, 2006). Also, the proportion of resistance assessments is 10 times higher for the period of 2001–2005 than for 1976–2000 (Table 1).

The resistance of two- and six-rowed varieties could be evaluated separately since 1994. The same period was also used for a more detailed analysis of resistance in domestic and foreign varieties included in trials in the periods of 1994–2000 and 2001–2005. The resistance of all two-rowed varieties was very similar in comparison with all six-rowed varieties. These results document that the resistance of two-rowed varieties is not generally lower as sometimes reported.

The analysis resulted in an important finding that while the resistance of all domestic and foreign varieties was very similar in 1994–2000 (foreign varieties were of 0.06 points less resistant), the resistance increased by 0.87 in domestic varieties and by 1.47 in foreign varieties in 2001–2005. Then, during such a short period the difference in the resistance of domestic and foreign varieties changed from +0.06 to –0.75 for domestic ones. It demonstrates considerably better results of foreign breeders in breeding both two- and six-rowed winter barley varieties for powdery mildew resistance.

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