Severity of Powdery Mildew on Winter Barley in the Czech Republic in 1976–2005

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Abstract

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Results of scoring the reaction to powdery mildew of 240 winter barley varieties that were gradually included in 392 Czech Official Trials conducted at 21 locations were analysed. The reaction of the varieties was determined on the basis of the level of infection by the disease. Therefore, the data can also be used to assess the disease severity in years and at locations. Several characteristics indicative of disease severity were considered, including the disease severity coefficient (= average infection of susceptible varieties in trials with a high disease severity/the proportion of such trials). The value of the coefficient is inversely proportional to disease severity. The highest powdery mildew severity was found in 1976, and the years 1988, 1990 and 2003 were characterised by high infection of the examined varieties. In contrast, the disease was practically absent in 1979 and 1982, and its severity was also low in 1978, 1981, 1985, 1991 and 1998. Very low disease severity was found for the period 1977–1982 when insufficient disease severity was found on average in 78% of the trials and high disease severity in only 6% of the trials. The highest disease severity was found at locations Trutnov, Horažďovice and Chrastava. The analysis of data from a large number of field trials conducted at various locations for a period of 30 years confirmed that powdery mildew is an important disease of winter barley in the Czech Republic. Known genetic sources of resistance and current methods, such as marker assisted selection, enable breeders to solve this problem.

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

Barley has a long history as a domesticated crop, as one of the first to be adopted for cultivation (Bothmer *et al.* 2003). In the Czech Republic, barley is the second most widely grown cereal after wheat, and its harvested area averaged 505 000 ha from 2001 to 2005. Twenty-five percent of the area is winter type of both two-rowed and six-rowed varieties. The latter predominate, but half of the varieties tested in the Czech Official Trials in 1996–2005 were two-rowed (Dreiseitl 2006). Winter barley is mainly grown for grain to supplement nutrition in farm animals, although two-rowed varieties are also bred for potential use as a low-cost raw material for malt production, which could be exported to countries with specific requirements.

The cultivated area of winter barley has undergone dramatic changes during the last 30 years. From 1971 to 1977, the mean annual area of the crop was 6000 ha, whereas it amounted to 214 000 ha in

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1988–1991. Such a rapid increase in the area was due to the development of varieties with improved winter hardiness. The decline in the area to the current level of 128 000 ha (mean of 2001–2005) mostly reflects marketing problems.

Powdery mildew, caused by *Blumeria graminis* (DC.) Golovin ex Speer f.sp. *hordei* Em. Marchal (*B.g.h.*), is the most widespread disease of spring as well as winter barley in the Czech Republic (Dreiseitl 2003a; Dreiseitl & Jurečka 1997, 2003). Under Central European conditions, *B.g.h.* survives mostly in a vegetative form, i.e. mycelium that produces conidia. There are two periods critical for its survival every year. In winter, far fewer living organs of the host are present and the pathogen grows slowly. In summer, particularly at and after maturity of the crop, green organs of the host are almost absent. At the end of the growing season, the fungus produces abundant chasmothecia (Braun *et al.* 2002) containing asci with ascospores. During this teleomorphic stage, genes that condition different traits including virulence may recombine.

Winter barley plays a key role in the overwintering of the pathogen, for its reproduction in spring and also for its adaptability (Dreiseitl 2003b). The disease reduces grain yield, its feeding and malting quality and, consequently, profitability of farmers. Therefore, high attention is paid to the problem of powdery mildew on the crop. The objective of this paper was to judge different characteristics documenting the disease severity on winter barley during a long period, similar to a study on spring barley (Dreiseitl & Jurečka 2003).

MATERIALS AND METHODS

The reaction of a variety is defined by the level of natural infection by the disease on it. Therefore, the data from variety trials can also be used to assess the disease severity. This is inversely proportional to the resistance of a variety. Therefore, in some cases the data are presented as variety infection/resistance.

Trial types. Results of evaluation of variety infection in two types of the Czech Official Trials were used. The goal of the first type was to determine the level of agronomically important traits (including powdery mildew resistance) of, usually, new varieties aiming at their registration. This type is called "registration trials". The goal of the second type was to check the level of agronomically important traits of registered varieties, and therefore this type is designated "check trials".

Years and locations. Results of registration trials over a period of 30 years (1976–2005) and check trials over a period of 10 years (1996–2005) were analysed (harvest years are always given). The trials were conducted at 21 locations across the Czech Republic, the registration trials at 20 locations and the check trials at 16 locations (Table 1).

Trials. During the period studied, 286 registration trials and 107 check trials were conducted. In 1991, data from a registration trial at Svitavy are missing, therefore only 285 registration trials were evaluated (Tables 1 and 2). Trials exhibiting a mean of variety infection/resistance of ≤ 6 (after eliminating the data on resistant varieties with a mean of resistance > 7.5) were considered as trials with high disease severity. Trials in which at least one variety was scored ≤ 6, but did not reach the parameter of the previous category, are considered as trials with low disease severity. Both categories were considered as trials with sufficient disease severity. Trials in which none of the varieties was scored ≤ 6 were considered to have insufficient disease severity and were excluded from further evaluation.

Varieties and data. A total of 240 varieties were tested. Varieties with a resistance of > 7.5 at locations with sufficient disease severity in a year were considered resistant (for details see Dreiseitl 2007b). During the period studied 4376 data from registration trials and 1377 data from check trials were evaluated (Tables 2 and 3).

Scoring scale and scoring procedure. A 1–9 scale was used to score the infection/resistance of barley to powdery mildew in the field: 1 = high susceptibility (extreme infection of entire plants), 9 = complete resistance (plants free of any visible symptoms). Infection levels of ≤ 4 on a variety are considered as high infection (low resistance). From 1976 to 1988, the infection/resistance of each variety was characterised by one scoring datum. From 1989 to 2005, the score of the infection/resistance was based on the mean of two to four replications.

Disease severity. To determine the powdery mildew severity at locations, the following three characteristics were analysed: the proportion of trials with insufficient disease severity; the proportion of trials with high disease severity; and the proportion of data on high infection related to the total number of data at a location (Table 1). The disease severity in individual years was de-

Table 1. Numbers of variety trials according to severity of powdery mildew and numbers of data on very high powdery mildew infection of winter barley, both characterising disease severity at 21 locations of the Czech Official Trials (registration trials 1976–2005, and check trials 1996–2005)

Location	Total number of trials			Number of trials with												Number of data						
				insufficient disease				low disease				high disease				total			of which ≤ 4			
	R	C	Sum	R	C	Sum	(%)	R	C	Sum	(%)	R	C	Sum	(%)	R	C	Sum	R	C	Sum	(%)
Horažďovice	11	9	20	4	1	5	25	0	6	6	30	7	2	9	45	81	116	197	27	5	32	16.2
Chlumec n. Cidl.	12	2	14	6	2	8	57	3	0	3	21	3	0	3	21	78	33	111	7	0	7	6.3
Chrastava	26	10	36	7	0	7	19	13	4	17	47	6	6	12	33	597	130	727	53	18	71	9.8
Jaroměřice	22	8	30	11	1	12	40	6	5	11	37	5	2	7	23	472	101	573	9	2	11	1.9
Krásné Údolí	3	0	3	3	0	3	100	0	0	0	0	0	0	0	0	29	0	29	0	0	0	0
Kroměříž	0	3	3	0	0	0	0	0	2	2	67	0	1	1	33	0	49	49	0	4	4	8.2
Kujavy	17	6	23	8	5	13	57	6	0	6	26	3	1	4	17	138	80	218	4	1	5	2.3
Lednice	4	0	4	3	0	3	75	1	0	1	25	0	0	0	0	34	0	34	1	0	1	2.9
Libějovice	13	10	23	4	4	8	35	2	4	6	26	7	2	9	39	114	130	244	9	2	11	4.5
Lípa	11	1	12	4	1	5	42	5	0	5	42	2	0	2	17	133	18	151	2	0	2	1.3
Lužany	4	9	13	3	5	8	62	1	4	5	38	0	0	0	0	194	116	310	4	1	5	1.6
Měšice	1	0	1	1	0	1	100	0	0	0	0	0	0	0	0	5	0	5	0	0	0	0
Nechanice	17	6	23	8	4	12	52	8	1	9	39	1	1	2	9	248	67	315	1	4	5	1.6
Oblekovice	14	3	17	3	1	4	24	6	1	7	41	5	1	6	35	113	34	147	5	2	7	4.8
Přerov n. L.	9	0	9	7	0	7	78	2	0	2	22	0	0	0	0	64	0	64	0	0	0	0
Staňkov	27	10	37	11	3	14	38	9	4	13	35	7	3	10	27	554	130	684	29	6	35	5.1
Svitavy	25	9	34	12	6	18	53	11	3	14	41	2	0	2	6	526	116	642	10	0	10	1.6
Trutnov	13	3	16	2	0	2	12	6	0	6	38	5	3	8	50	114	31	145	14	11	25	17.2
Vysoká	24	11	35	15	8	23	66	8	3	11	31	1	0	1	3	528	136	664	3	0	3	0.5
Vyškov	1	0	1	0	0	0	0	1	0	1	100	0	0	0	0	10	0	10	0	0	0	0
Žatec	19	7	26	6	1	7	27	10	2	12	46	3	4	7	27	344	90	434	48	16	64	14.7
Sum	*285	107	*392	*130	42	*172	44	98	39	137	35	57	26	83	21	4376	1377	5753	226	72	298	5.2

R – registration trials; C – check trials; *In 1982, insufficient disease severity was found at all 12 locations of registration trials and since no results from this year were published, these locations are unknown; their number is included in line Sum, but not in lines of individual locations

Table 2. Characterisation of powdery mildew severity on winter barley in the Czech Official Trials (registration trials), 1976–2005

Year	n	Number				Disease severity						Mean of variety infection				Difference in infection		Very high infection		Disease severity coefficient
		varieties		data*		insufficient[1]		low[2]		high[3]										
		A	B	C	D	n	(%)	n	(%)	n	(%)	E	F	G	H	I	J	K	L	
1976	5	7	6	35	24	0	0	1	20	4	80	5.86	5.53	7.80	5.38	0.48	2.42	10	5	6.7
1977	8	5	3	40	3	5	63	2	25	1	12	6.67	6.33	7.67	5.50	1.17	2.17	1	1	45.8
1978	11	5	4	55	0	10	91	1	9	0	0	6.60	6.25	8.00	–	–	–	0	0	–
1979	a3	6	–	18	–	3	100	0	0	0	0	–	–	–	–	–	–	0	0	–
1980	14	5	5	70	10	10	71	2	14	2	14	5.85	5.85	–	5.10	0.75	–	2	1	36.4
1981	15	4	4	60	4	9	60	5	33	1	7	6.42	6.42	–	5.33	0.89	–	1	1	76.1
1982	[a]12	4	–	–	–	12	100	0	0	0	0	–	–	–	–	–	–	0	0	–
1983	15	5	4	75	12	7	47	5	33	3	20	6.20	5.69	8.25	4.33	1.87	3.92	10	3	21.6
1984	13	6	5	78	20	5	38	4	31	4	31	6.38	6.10	7.75	5.00	1.38	2.75	8	3	16.1
1985	14	7	6	98	6	5	36	8	57	1	7	6.98	6.87	7.67	5.83	1.15	0.84	2	2	83.3
1986	13	8	8	104	16	7	54	4	31	2	15	6.63	6.63	–	5.86	0.77	–	1	1	39.1
1987	17	10	10	170	20	5	29	10	59	2	12	6.79	6.79	–	5.43	1.36	–	4	3	45.2
1988	15	9	9	135	63	6	40	2	13	7	47	5.67	5.67	–	5.24	0.43	–	20	6	11.2
1989	15	10	10	150	20	5	33	8	53	2	13	6.43	6.43	–	4.70	1.73	–	8	2	36.2
1990	12	11	11	132	66	2	17	4	33	6	50	6.13	6.13	–	5.53	0.60	–	11	2	11.1
1991	12	11	8	132	8	6	50	5	42	1	8	7.10	6.76	8.00	5.63	1.47	2.37	0	0	70.4
1992	11	12	11	132	22	3	27	6	55	2	18	6.62	6.52	7.73	5.24	1.38	2.49	6	2	29.1
1993	10	16	15	160	60	2	20	4	40	4	40	6.21	6.09	8.10	5.56	0.65	2.54	7	3	13.9
1994	6	16	13	96	13	2	33	3	50	1	17	6.98	6.82	7.67	5.32	1.66	2.35	0	0	31.3
1995	6	17	17	102	34	4	67	0	0	2	33	4.96	4.96	–	4.96	0.00	–	9	1	15.0
1996	6	25	24	150	48	1	17	3	50	2	33	6.54	6.49	7.72	5.03	1.51	2.69	12	1	15.2
1997	6	38	37	228	37	2	33	3	50	1	17	6.70	6.68	7.58	4.61	2.09	2.97	4	1	27.1
1998	6	43	14	258	0	4	67	2	33	0	0	7.79	6.77	8.29	–	–	–	0	0	–
1999	6	46	46	276	46	3	50	2	33	1	17	5.09	5.09	–	2.84	2.25	–	40	2	16.7
2000	6	44	41	264	82	0	0	4	67	2	33	6.33	6.21	8.00	5.23	1.10	2.77	11	2	15.8
2001	7	46	42	322	84	2	29	3	43	2	29	6.34	6.20	7.75	5.28	1.06	2.47	18	2	18.2
2002	7	[b]55	25	210	25	4	57	2	29	1	14	6.56	6.31	7.82	4.99	1.57	2.83	8	2	35.6
2003	1	53	41	53	41	0	0	0	0	1	100	6.06	5.56	7.78	5.56	0.50	2.22	8	1	5.6
2004	5	57	53	285	53	1	20	3	60	1	20	6.80	6.70	8.18	5.76	1.04	2.42	10	2	28.8
2005	8	61	50	488	50	5	62	2	25	1	12	6.52	6.18	8.04	5.30	1.22	2.74	15	2	44.2
Sum	285	642	528	4376	867	130	46	98	34	57	20	6.40	6.22	7.88	5.17	1.23	2.71	226	51	24.6

termined in a similar way using also the mean of infection of all varieties in trials with sufficient disease severity and the disease severity coefficient (Tables 2 and 3).

Disease severity coefficient. The disease severity coefficient comprises infection intensity of non-resistant varieties (after eliminating the data on resistant varieties with a mean of resistance > 7.5) in trials with high disease severity, and the proportion of such trials of the total number of trials. It was calculated as follows: average infection of non-resistant varieties in trials with high disease severity in a year/the proportion of trials with high disease severity in a year. A value of the coefficient is inversely proportional to disease severity.

RESULTS

Data on powdery mildew infection in 285 registration trials and 107 check trials in which 240 winter barley varieties were gradually included from 1976 to 2005 (check trials 1996–2005), were analysed. The 4376 and 1377 data were used to calculate the frequencies of classes of infection/resistance to be presented in tables, and for proportions given in the text.

Disease severity at locations

Proportion of trials with insufficient disease severity. The proportion of trials with insufficient severity of powdery mildew exceeded 60% of the trials (Table 1) conducted at the six locations Krásné Údolí, Měšice (both 100%), Lednice (75%), Přerov n. L. (78%), Vysoká (66%) and Lužany (62%). However, only a small number of trials (1 to 4) were conducted at the first three of them. A low proportion of trials with insufficient disease severity (25% or less) was found at Trutnov (12%), Chrastava (19%), Oblekovice (24%) and Horažďovice (25%), and also at Kroměříž and Vyškov (both 0%) where a small number of trials were conducted.

Proportion of trials with high disease severity. At Trutnov, the proportion of trials with high disease severity reached 50% (Table 1) and at a further five locations it reached or exceeded 33% (Horažďovice 45%, Libějovice 39%, Oblekovice 35%, Chrastava 33%, and Kroměříž 33%, but only three trials were conducted at the last named location). None of six locations (Krásné Údolí, Lednice, Měšice, Vyškov, Přerov n. L., and Lužany) showed a high disease severity (a low number of trials were conducted at the first four of these locations). No trial with high disease severity was found at six locations.

Proportion of data on high infection related to the total number of data. The five highest proportions of data on high infection were at Trutnov (17.2%), Horažďovice (16.2%), Žatec (14.7%), Chrastava (9.8%), and Kroměříž (8.2%). No data on high infection of a variety were found at four locations (Měšice, Vyškov, Krásné Údolí, and Přerov n. L.). However, all of them, but mainly the first two locations, had only few data (Table 1).

Disease severity in years

Proportion of trials with insufficient disease severity. Of 392 trials conducted (285 + 107), the results from 172 (44%) were excluded due to insufficient disease severity (Tables 2 and 3). The highest proportion of these trials was recorded in 1979 and 1982 (100%), in 1978 (91%), 1980 (71%) and in 1995 (67%). In contrast, no trial was excluded in the first year of the study (1976) and the proportion of excluded trials was 20% or less

Explantion to Table 2

[a]the disease did not occur; [b]only 30 varieties were evaluated; n – number of trials; data* = $n \times$ A; [1]trials in which no variety reached infection by powdery mildew scored ≤ 6 (according to the 1–9 scale: 9 = fully resistant, plants are free of visible symptoms of infection); [2]trials with low disease severity (at least one variety was infected ≤ 6.0, but does not reach infection of the trials[3]); [3]trials with high disease severity (the mean of infection of the tested varieties, after eliminating resistant varieties, is ≤ 6.0); A – total number of tested varieties; B – number of non-resistant varieties (resistance ≤ 7.5); C – number of trials (n) × number of tested varieties (A); D – number of trials[3] × number of non-resistant varieties (B); E – mean of infection of all varieties in the trials[2+3]; F – mean of infection of non-resistant varieties in the trials[2+3]; G – mean of infection of resistant varieties in the trials[2+3]; H – the mean of infection of non-resistant varieties in the trials[3]; I = E – H; J = G – H; K – number of data on very high infection of varieties (≤ 4); L – number of trials in which very high infection of the variety(ies) was found; disease severity coefficient = H/proportion of trials with high disease severity[(3)], the coefficient is inversely proportional to disease severity

Table 3. Characterisation of powdery mildew severity on winter barley in the Czech Official Trials (check trials), 1996–2005

Year	n	Number				Disease severity						Mean of variety infection				Difference in infection		Very high infection		Disease severity coefficient
		varieties		data*		insufficient[1]		low[2]		high[3]										
		A	B	C	D	n	(%)	n	(%)	n	(%)	E	F	G	H	I	J	K	L	
1996	13	9	9	117	36	2	15	7	54	4	31	6.41	6.41	–	5.30	1.11	–	5	2	17.1
1997	14	11	11	154	22	6	43	6	43	2	14	6.34	6.34	–	3.93	2.41	–	14	2	28.1
1998	12	11	9	132	9	5	42	6	50	1	8	7.11	6.93	7.91	5.79	1.32	2.12	0	0	72.4
1999	11	12	12	132	48	6	55	1	9	4	36	5.13	5.13	–	4.87	0.26	–	15	3	13.5
2000	10	11	10	110	20	2	20	6	60	2	20	6.51	6.37	7.95	5.00	1.51	2.95	2	1	25.0
2001	10	13	12	130	48	3	30	3	30	4	40	5.77	5.60	7.73	5.01	0.76	2.72	11	4	12.5
2002	11	16	14	176	14	6	55	4	36	1	9	6.57	6.38	7.87	4.89	1.68	2.98	4	1	54.3
2003	3	14	13	42	13	2	67	0	0	1	33	5.60	5.42	8.00	5.42	0.18	2.58	3	1	16.4
2004	10	15	14	150	56	2	20	4	40	4	40	6.07	5.96	7.68	5.35	0.72	2.33	8	4	13.4
2005	13	18	16	234	48	8	62	2	15	3	23	6.12	5.90	7.87	5.20	0.92	2.67	10	3	22.6
Sum	107	(29)	(28)	1377	314	42	39	39	37	26	24	6.23	6.04	7.84	5.08	1.09	2.62	72	21	27.5

n – number of trials; data* = $n \times$ A; [1]trials in which no variety reached infection by powdery mildew scored ≤ 6 (according to the 1–9 scale, 9 = fully resistant, plants are free of visible symptoms of infection); [2]trials with low disease severity (at least one variety was infected ≤ 6.0, but does not reach infection of the trials[3]); [3]trials with high disease severity (the mean of infection of the tested varieties, after eliminating resistant varieties, is ≤ 6.0); A – total number of tested varieties; B – number of non-resistant varieties (resistance ≤ 7.5); C – number of trials (n) × number of tested varieties (A); D – number of trials[3] × number of non–resistant varieties (B); E – mean of infection of all varieties in the trials[2+3]; F – mean of infection of non-resistant varieties in the trials[2+3]; G – mean of infection of resistant varieties in the trials[2+3]; H – the mean of infection of non-resistant varieties in the trials[3]; I = E – H; J = G – H; K – number of data on very high infection of varieties (≤ 4); L – number of trials in which very high infection of the variety(ies) was found; disease severity coefficient = H/proportion of trials with high disease severity[(3)], the coefficient is inversely proportional to disease severity in 2000 (12%), 1996 (16%), 1990 (17%), 1993 (20%) and 2004 (20%).

Proportion of trials with high disease severity. Eighty-three trials (21%) showed a high disease severity (Tables 2 and 3). Such trials were found each year except 1978, 1979 and 1982. The highest proportions of these trials were recorded in 1976 (80%), 1990 and 2003 (both 50%) and in 1988 (47%), and the lowest proportions were recorded in 1998 (6%), 1981 and 1985 (both 7%) and 1991 (8%).

Mean of infection of all varieties in trials with high disease severity. The highest mean of infection was recorded in 1995 (4.96), in 1999 in both types of trials (5.09 in registration trials and 5.13 in check trials), in 1988 (5.67), 1980 (5.85) and 1976 (5.86). In contrast, the lowest mean of infection (= the highest mean of resistance) was recorded in 1998, again in both types of trials (7.79 in registration trials and 7.11 in check trials) and in registration trials in 1991 (7.10), 1985 and 1994 (both 6.98) (Tables 2 and 3).

Proportion of data on high infection related to the total number of data. The six highest proportions of data on high infection were in 1976 (28.6%), 1988 (14.8%), 1999 (13.5%), 1983 (13.3%), 2003 (11.6%) and in 1984 (10.3%). No data on high infection of a variety were found in six years (1978, 1979, 1982, 1991, 1994 and 1998) (Tables 2 and 3).

Disease severity coefficient. The lowest values of this coefficient (= the highest disease severity) were found in registration trials in 2003 (5.56) and in 1976 (6.72) (Table 2). Low values of this coefficient (< 12.50) were also found in 1988 and 1990. The highest disease severity coefficients (= the lowest disease severity) were found in 1985 (83.28), 1981 (76.14) and 1991 (70.38), and in check trials in 1998 (72.38). In 1978, 1979, 1982 and 1998 (registration trials), this coefficient could not be calculated due to absence of trials with high disease severity.

DISCUSSION

Powdery mildew severity is conditioned by the actual inoculum potential of the pathogen, the resistance level of host varieties and the environment. Since these factors influence one another in the analysed type of trials, it is difficult to determine the effect of each single factor. Therefore, the results were grouped into several characteristics and analysed from various points of view.

Out of the 21 locations, high disease severity was frequent at Trutnov, Horažďovice and Chrastava, but also at Oblekovice, Žatec and Kroměříž which could thus be considered as locations suitable for evaluating the resistance of winter barley varieties to powdery mildew. In contrast, Krásné Údolí, Měšice and Lednice (low number of trials), but also Přerov n. L., Lužany and Vysoká were highly unsuitable for evaluating the resistance of winter barley varieties because of the generally low disease severity (high proportion of trials with insufficient disease, no trials with high disease and no or very low data on high infection).

Among the 30 analysed years, the highest powdery mildew severity was found in 1976. The years 1988, 1990 and 2003 were also characterised by high infection of the examined varieties. In contrast, the disease was practically absent in 1979 and 1982, and its severity was also low in 1978, 1981, 1985, 1991 and 1998. Very low disease severity was found in 1977–1982 when insufficient disease severity was found on average in 78% of trials and high disease severity in only 6% of the trials. Unique results were obtained in 1995 when six trials were conducted in which disease severity was polarised. While the infection was low (insufficient) in four trials, and based on the proportion of these trials the year 1995 ranked among the 6 years with the lowest disease severity, the average infection in the two remaining trials was the highest for the whole period studied. Except for the first 7 years (year 1976 with the highest disease severity was followed by a 6-year period with low disease severity), no time period was recorded that would be characterised by considerably higher or, conversely, considerably lower disease severity.

All varieties included in the check trials had first been examined in registration trials. Considering the examined parameters, the check trials exhibited slightly higher infection. It is likely due to a shift in variety age, at least in two directions. Firstly, breeding winter barley varieties has been fruitful particularly in recent years due to an increasing proportion of resistant varieties (Dreiseitl 2007b), mostly of newer varieties. Thus, if the varieties are included in check trials later (usually for 3 years), such a delay in the release of more resistant varieties results in slightly lower resistance of the entire examined set. Secondly, the shift is also caused by the fact that the resistance of varieties is substantially controlled by specific-resistance genes (Dreiseitl 2007a), many of which have been partly overcome by the pathogen population since it contains a certain proportion of individuals that are virulent for corresponding resistance genes (Dreiseitl 2004). Consequently, the increasing proportion of virulent individuals of the pathogen gradually induces increasing infection on varieties possessing those resistance genes (Dreiseitl 2003b). Thus, if such varieties are included in check trials after passing 3 years registration trials, in some cases their resistance is lower.

A good example of the interrelationship between resistance of varieties and disease severity is the year 1976. It was assessed as the year with the highest disease severity, with disease severity being derived from the infection of examined varieties. In 1976, seven varieties were tested, out of which the varieties Bollo and Polaris had the highest number of data of low resistance determined in one variety in one year. Of course, such a high infection of the two varieties (= almost 30% of varieties examined in the given year) substantially affected the evaluation of disease severity in the given season. That raises the question whether disease severity in 1976 was that high as to induce extreme infection of the two varieties, or conversely, whether the resistance of these varieties was as low as to considerably affect the evaluation of the whole year.

In variety trials, the plots planted with susceptible varieties may alternate with plots of resistant varieties. The latter do not allow the pathogen to reproduce and spread so that plots of susceptible varieties tend to be infected less than in a larger field. Therefore, in this type of trials, the average infection of susceptible varieties decreases, particularly with an increasing proportion of resistant varieties. For the same reason, the proportion of trials with a high disease severity also decreases. In fact, it limits the accuracy of variety trials for evaluating disease severity. Therefore, the actual severity of powdery mildew in a region may even be higher than can be inferred from the results of such trials (Dreiseitl & Jurečka 2003).

During the period studied, the area planted to winter barley dramatically changed (Dreiseitl & Jurečka 2003). The smallest areas of winter barley for at least the last 50 years were recorded in 1975 and 1976 (5000 ha each year). In 1975, the winter barley area accounted for 0.76% of total barley area, whereas in 1991 for 41.7% (243 000 ha), and for 25.0% in 2001–2005. As for the severity of the studied disease, spring barley and winter barley certainly affect each other. Both the ratio of areas of the two crops and the ratio of resistant/susceptible varieties in each are significant. This can be one of the reasons why the period with the lowest disease severity on winter barley (1977–1982) coincided with the period of the largest areas under resistant varieties of spring barley (Dreiseitl 1993).

The analysis of data from a large number of field trials conducted at various locations for a period of 30 years confirmed that powdery mildew is an important disease of winter barley in the Czech Republic. Trials with high powdery mildew severity were found in 27, and data of very high infection of varieties occurred in 24 out of the 30 years. Evidently, the presence of winter barley varieties with an insufficient resistance to powdery mildew allows a lasting high inoculum potential of the pathogen.

Powdery mildew ranks high among cereal pathogens for its adaptability and ability to cause crop loss (McDonald & Linde 2002). To combat this pathogen, cultivars must be bred that possess effective resistance genes for which there are no, or very rare, corresponding virulence genes in the existing pathogen population. The use of two or more effective genes in one cultivar is desirable, and should limit the speed of adaptation by pathogen and thus extend the effectiveness of cultivar resistance to powdery mildew in winter barley. Current methods, such as marker assisted selection, enable breeders to detect combinations of those genes (Řepková *et al*. 2006).

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