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# FREQUENCY OF POWDERY MILDEW RESISTANCES IN WINTER BARLEY CULTIVARS TESTED IN DOMESTIC VARIETY TRIALS

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## Abstract

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In 2006–2010, resistance to the powdery mildew pathogen was studied in 225 winter barley cultivars of which 86 two-rowed and 139 six-rowed. The examined set included 59 cultivars tested in the official variety trials and 166 cultivars in variety trials conducted by domestic breeding stations in that period. Thirteen known resistances were identified (Ar, Bw, Dr2, Ha, HH, IM9, La, Ly, Ra, Ru, Sp, St and We). No resistance was found in one cultivar only. The most frequent resistance was Ra detected in 114 cultivars (= 50.7%). The resistance Bw was found in 54 cultivars (24.0%). Resistances typical for spring barley cultivars (Ly, Sp, Ru and We) were also frequent (4.0% to 23.6%). Unknown resistances were found in 20 cultivars, in nine of which they were effective to all used pathotypes of the pathogen. Thirty-six cultivars (16.0%) exhibited heterogeneity in the examined trait, i.e. they were mostly composed of lines with different resistances. Research on cultivars possessing unknown resistances continues.

*Blumeria graminis* f.sp. *hordei*, *Hordeum vulgare*, postulation of resistances, powdery mildew, winter barley

Winter barley (*Hordeum vulgare* L.) is a crop that has undergone dramatic changes in the Czech Republic over the last three decades. These changes can be characterised by the six following parameters: 1) growing areas – they were on average of 1971–1977 6,000 ha, then enlarged up to 243,000 ha in 1991 when cv. Borwina was predominating, and in 2006–2010 they were stabilized on average of 124,000 ha; 2) the proportion of registered domestic and foreign cultivars – only foreign cultivars were registered in 1972–1989, then seven domestic cultivars were registered in 1990–1998 and dominated among nine six-rowed cultivars registered in 1998, however, in the following period 45 foreign and only two domestic cultivars were registered; 3) the proportion of grown domestic and foreign cultivars – only foreign cultivars were grown in 1972–1989, then there was a dramatic increase in new domestic cultivars exceeding 75% in each of the years from 1994 to 1999, followed by a rapid fall of domestic cultivars to about 3% in 2008–2010; 4) the proportion of registered six-rowed and two-rowed cultivars – only six-rowed cultivars had been grown by 1992, in 1993 the first two-rowed cv. Marinka was registered, followed by other 18 foreign cultivars as long as the first domestic two-rowed cv. Florian was registered in 2008; 15 two-rowed and 24 six-rowed cultivars were registered in June 2010; 5) the proportion of grown six-rowed and two-rowed cultivars – growing two-rowed cultivars was not common in the Czech Republic, nevertheless, after registration of first such cultivars their proportion slowly increased and exceeded 25% in each of the years 2001 to 2004, whereas they were grown on average of 2006–2010 on less then 10%; and finally 6) utilization of grain production – in the past, winter barley was used for feeding farm animals only, however, two-rowed cultivars has begun to be partly used for malt production.

Breeding winter barley in the Czech Republic had been conducted on three places, of which six-rowed cultivars by the Breeding Station Lužany and two-rowed cultivars by the Breeding Station Chlumec nad Cidlinou. Both types had also been bred at the Agricultural Research Institute Kromeriz Ltd. In 2008, however, the breeding of two-rowed cultivars was terminated in Chlumec nad Cidlinou and in Kroměříž. Thus, only breeding six-rowed cultivars is now conducted.

Dreiseitl a Jurečka (1997) studied disease severity on winter barley and they found that 40% of all detected epidemics was caused by the fungus *Blumeria graminis* (DC.) E. O. Speer, f.sp. *hordei* emend. É. J. Marchal (anamorph *Oidium monilioides* Link) (= *Bgh*). Dreiseitl (2007a) analysed winter barley infected by the powdery mildew pathogen in 285 official variety trials performed in 1976–2005. The results revealed that on average 20% of winter barley area was heavily infected by this pathogen every year and the disease was not found on winter barley only in two of the 30 years (1979 and 1982). During the same period, the resistance of cultivars to the mildew pathogen was also examined in the field. Over the whole period, only six winter barley cultivars (= 1.7%) were classified to be resistant (Dreiseitl, 2007b). Other three papers were aimed at postulating specific-resistances in various sets of winter barley cultivars (Dreiseitl, 2005; 2006; 2007c). At the same time a study of the given pathogen (Dreiseitl, 2004) was focused on determining the effectiveness of specific resistances. Except cvs. Carola, Duet and Vanessa, the corresponding virulence frequencies exceeded 80%. However, another study (Dreiseitl, 2008) reports cultivars possessing effective resistances (Florian and especially Laverda). To increase the resistance of domestic cultivars, sources of resistance began to be studied (Řepková *et al*., 2009a; 2009b; Řepková a Dreiseitl, 2010; Teturová *et al*., 2010).

The objective of the present paper was to summarize data on the postulation of resistance to the powdery mildew pathogen in winter barley cultivars tested in domestic variety trials conducted in 2006–2010.

## MATERIAL AND METHODS

Resistances were identified using the postulation method (Brückner, 1964; Statler, 1984; Jensen *et al*., 1992; and others).

**Barley germplasm.** Two hundred and twenty-five winter barley cultivars tested in 2006–2010 including 86 two-rowed and 139 six-rowed cultivars were studied. They were represented by 59 cultivars tested in Czech official variety trials, and 166 cultivars bred and evaluated in variety trials conducted by breeding stations Lužany and Chlumec nad Cidlinou of the Selgen Ltd. company. Seed of all cultivars was provided by respective breeders.

**Pathogen isolates.** Thirty-two (40 in 2009) pathotypes of *Bgh* held in the genebank at the Agricultural Research Institute Kroměříž Ltd. were used for resistance tests. 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 the differential hosts and increased on susceptible cultivars.

**Testing procedure.** In 2006–2008, young plants were used for resistance tests (Dreiseitl, 2007c). In 2009 and 2010, the resistance tests were conducted on leaf segments as follows. About 40 seeds of each barley cultivar were sown evenly into two pots (80mm diameter) filled with a gardening peat substrate and placed in a mildew-proof greenhouse under natural daylight. Leaf segments 20 mm long were cut from the central part of healthy fully-expanded primary leaves. Three leaf segments of each accession were placed in a Petri dish on water agar (0.8% and 40 ppm benzimidazole) for testing with an isolate. For each isolate, a Petri dish with leaf segments was placed at the bottom of a metal inoculation tower and inoculated with inoculum density ca. 8 conidia $mm^{-2}$. The dishes with inoculated leaf segments were incubated at 18 ± 3 °C under artificial light (cool-white fluorescent lamps providing 12 h light at 30 ± 5 μmol $m^{-2}$ per s).

**Evaluation.** Eight to ten days after inoculation, reaction types (RTs) on the upper part of the adaxial side of leaf segments were scored. The nine RTs scale (0–4 including intermediate types) was used for scoring (Torp *et al*., 1978). Each cultivar was tested in two replications. If there were significant differences between replications in RTs, additional tests were carried out. A set of 32 or 40 RTs developed after inoculation with selected pathogen isolates provided the basis for a resistance spectrum (RS) of each cultivar. The resistance in each cultivar was postulated by comparing its RS with previously determined RSs of standard barley lines possessing known resistance genes. The resistance spectra of the tested cultivars are included in protocols provided to individual breeders or the Czech official variety trials authority, and they are available at the author of this contribution. The found resistances were designated using European codes (Boesen *et al*., 1996). Three missing codes (H, HH and U(E)) were added (H = heterogeneous cultivars in terms of the trait studied, when after inoculation with at least one *Bgh* pathotype plants exhibited different reaction types and thus they were composed of two or more lines possessing different resistances; HH is designation after Heils Hanna, and U(E) means unknown resistance effective to all isolates of the pathogen used).

## RESULTS

A hundred and eighty-nine homogeneous cultivars and 36 heterogeneous cultivars (16.0%) in terms of the trait studied (after inoculation with at least one *Bgh* pathotype, their plants exhibited different RTs and thus they were mostly composed lines possessing different resistances) were found.

Individual cultivars possessed 0 to 5 resistances. No resistance was detected in CH 527 only, five resistances were detected in three homogeneous cultivars, SG-L 96/080/06, SG-L 98/010/07 and SG-L 3412/06, and in two heterogeneous cultivars, SG-L 99/070/05 and SG-L 3406/A/03. Some cultivars were tested repeatedly and cvs. F 12872 and CH-164 showed different results.

Thirteen known resistances were identified (Ar, Bw, Dr2, Ha, HH, IM9, La, Ly, Ra, Ru, Sp, St and We). Their numbers are given in Table I. The most frequent resistance was Ra detected in 114 cultivars (= 50.7%). The resistance Bw was found in 54 cultivars (24.0%). Some old resistances typical for spring barley cultivars (Ly, Sp, Ru and We) were also frequent (4.0% to 23.6%). Unknown resistances were found in 20 cultivars, in nine of which (= 4.0%) they were effective to all used pathotypes of the pathogen.

## DISCUSSION

The resistance of all cultivars tested in Czech official variety trials was examined every year till 2005 and the resistance of 41 winter barley cultivars registered in the Czech Republic from 1971 to 2005 was studied (Dreiseitl, 2007c). However, since 2006 only cultivars for the second and third year of the trials were tested for the resistance.

In 1996–2005, 167 winter barley cultivars in Czech official variety trials were tested, among which 17 known and other unknown resistances to powdery mildew were found. Six cultivars (3.6%) possessed unknown [U(E)] resistances effective to all of the employed pathotypes of the pathogen (Dreiseitl, 2006). In the present study, nine off 59 cultivars tested in Czech official variety trials (15.3%) with such a fully effective resistance were found. All fully resistant cultivars were of foreign origin and all, except Br.4190a1, were six-rowed. Three of these cultivars (Laverda, Souleyka and Wendy) have been registered and are the most resistant in a current set of winter barley cultivars.

Some cultivars studied here were tested repeatedly and their detected resistances were identical or were slightly affected by resolving power of a current set of pathotypes used. However, there were significant differences in cvs. F 12872 and CH 164. In 2008–2010, cvs. F 12861 (Jup) and F 12872 were repeatedly tested. The first of them displayed the resistance Sp Bw in all three tests. Nevertheless, cv. F 12872 exhibited heterogeneous resistance in 2008 when one line possessed also the resistance Sp Bw, whereas the second line the resistance Bw only. In the following years 2009 and 2010, cv. F 12872 was composed only of a line with the resistance Bw. It is possible that cv. F 12872 was heterogeneous due to segregating corresponding resistance genes in the first year of testing, whereas only Bw line was selected by a breeder for further testing. Also, a possibility of mechanical mixing cvs. F 12861 and F 12872 in 2008 cannot be excluded. In the case of cv. CH 164 the resistance St was found in 2006, whereas the resistance Ra Ha HH in 2008. Such a difference in the resistance could be caused by cultivar confusion only.

Cultivars resistant to the given pathogen in the field can be bred by cumulating of minor genes with a small effect, which are often assumed to be non-specific, or using of specific resistances. Except cv. CH 527, at least one specific resistance was found in each of 225 cultivars examined. However, the specific resistances are effective as long as the frequency of corresponding virulences of the given metapopulation is near 0%. Current virulence frequencies to all of 13 postulated resistances are high and near 100% in some of them (Dreiseitl, 2008). Therefore, neither such resistances nor their combinations are of greater importance to cultivar resistance in the field. In contrast, most detected unknown resistances are characterized by high effectiveness against the current population of the pathogen. To keep sufficient resistance durability for at least a natural life cycle of the cultivar, they should be combined among each other. Whether it is so at least in some of the cultivars examined here will be a subject of further research.

I: *Frequency of resistances to the powdery mildew pathogen found in 225 winter barley cultivars in variety trials in 2006–2010*

| Resistance[1] | No. of cultivars | Resistance | No. of cultivars |
|---|---|---|---|
| Ar | 1 | none | 1 |
| Bw | 54 | Ra | 114 |
| Dr2 | 44 | Ru | 18 |
| Ha | 71 | Sp | 53 |
| HH | 76 | St | 19 |
| IM9 | 23 | U | 20 |
| La | 4 | - of them U(E) | 9 |
| Ly | 14 | We | 9 |

[1]According to Boesen *et al.*, 1996; additional resistance codes used: HH – designated after Heils Hanna; U(E) = unknown resistance effective to all isolates of the pathogen used.

## SUMMARY

Barley (*Hordeum vulgare* L.) is an important crop in the Czech Republic. Powdery mildew caused by the fungal pathogen *Blumeria graminis* is the most prevalent disease of both spring and winter barley. Growing resistant varieties is a cost-effective and environment-friendly means of disease control. Therefore, breeding of barley for resistance to powdery mildew is one of the main objectives of crop improvement for both conventional and organic breeding programmes. A large number of barley specific resistances to powdery mildew is known. For their effective use in breeding and growing the knowledge of resistances in barley cultivars is crucial. Postulation is a traditional and still very effective method of resistance identification. It is based on host phenotype evaluation after inoculation of cultivars by a number of selected pathogen isolates. The objective of the present paper was to summarize data on the postulation of resistance to the powdery mildew pathogen in winter barley cultivars tested in domestic variety trials conducted in 2006–2010. Two hundred and twenty-five winter barley cultivars including 86 two-rowed and 139 six-rowed cultivars were studied. They were represented by 59 cultivars tested in Czech official variety trials, and 166 cultivars bred and evaluated in variety trials conducted by breeding stations Lužany and Chlumec nad Cidlinou of the Selgen Ltd. company. Thirteen known resistances were identified (Ar, Bw, Dr2, Ha, HH, IM9, La, Ly, Ra, Ru, Sp, St and We). No resistance was found in one cultivar only. The most frequent resistance was Ra detected in 114 cultivars (= 50.7%). The resistance Bw was found in 54 cultivars (24.0%). Resistances typical for spring barley cultivars (Ly, Sp, Ru and We) were also frequent (4.0% to 23.6%). Thirty-six cultivars (16.0%) exhibited heterogeneity in the examined trait, i.e. they were mostly composed of lines with different resistances. Unknown resistances were found in 20 cultivars and in nine off 59 cultivars tested in Czech official variety trials (15.3%) they were effective to all used pathotypes of the pathogen. All fully resistant cultivars were of foreign origin and all, except Br.4190a1, were six-rowed. Three of these cultivars (Laverda, Souleyka and Wendy) have been registered and are the most resistant in a current set of winter barley cultivars. Research on cultivars possessing unknown resistances continues.



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