Varietal resistance of barley as a rational way of decreasing leaf rust occurrence and harmfulness

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Occurrence of leaf rust and the other diseases of barley

In the Czech Republic, barley (*Hordeum vulgare* L.) is grown annually on more than 0.5 million hectares of which spring barley occupies ca. 70 %. Leaf rust (*Puccinia hordei* Otth) ranks second after powdery mildew (*Blumeria graminis* f. sp. *hordei*) among the most common diseases of barley (DREISEITL and JURECKA, 1995, 1996). An analysis of disease occurrence in the field variety trials conducted by the Central Institute for Supervising and Testing in Agriculture, Brno revealed that in the period from 1989 to 2000 severe disease incidence on spring barley was assessed for 210 from the total number of 320 trials. Of them, 61 trials were strongly infected by leaf rust (*Graph 1*).

During the same period, 145 field trials of winter barley were analyzed. Severe disease incidence was assessed in 103 trials, of which leaf rust caused epidemics in 15 (*Graph 2*) (DREISEITL and JURECKA, unpublished). Leaf rust occurrence on winter barley is about half in comparison with that on spring barley. More significant occurrence of the other rusts, such as *Puccinia striiformis* f. sp. *hordei*, *Puccinia graminis* (especially f. sp. *tritici*, but as well as f. sp. *secalis*) and even newly detected *Puccinia coronata* var. *hordei* (JIN and STEFFENSON, 1999), has not been found.

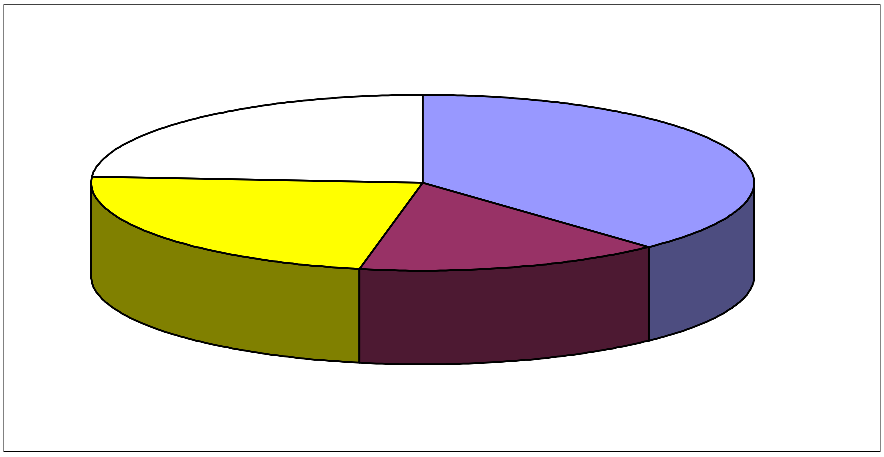

Figure 2: **Proportion of epidemics of winter barley diseases in 320 fields of the State Variety Trials (Czech Republic, 1989-2000)**

Disease epidemiology

The barley leaf rust fungus ranks among obligate parasites. To propagate, it needs assimilating organs of the host (barley). It is a typical leaf disease, however, it infects also stem and ear. It is propagated by urediniospores that can be transmitted by wind on long distances. At the end of the growing season, it produces teliospores but they are not able in any case to induce the disease on barley (ANIKSTER, personal communication). Basidiospores are produced by germination of teliospores, followed by nucleus fusion and reduction division; they are able to infect intermediate hosts only (mainly *Ornithogalum* L. species). Teliospores and alternate host may not be required for disease development. New pathotypes of the rust may also develop apart from an alternate host through mutation and parasexual mechanisms in the uredinial stage (MATHRE, 1997).

A critical period for leaf rust survival is the absence of the host. It is mostly the winter in northern Europe where winter barley is not grown in many areas at all. By contrast, it is a summer period in some areas of the Mediterranean region where the host (even volunteer plants) is absent due to early barley harvest and water deficiency. Thanks to growing winter barley, the situation is quite different in Central Europe. It is relatively easy for leaf rust to survive during the winter on winter barley. Volunteer plants

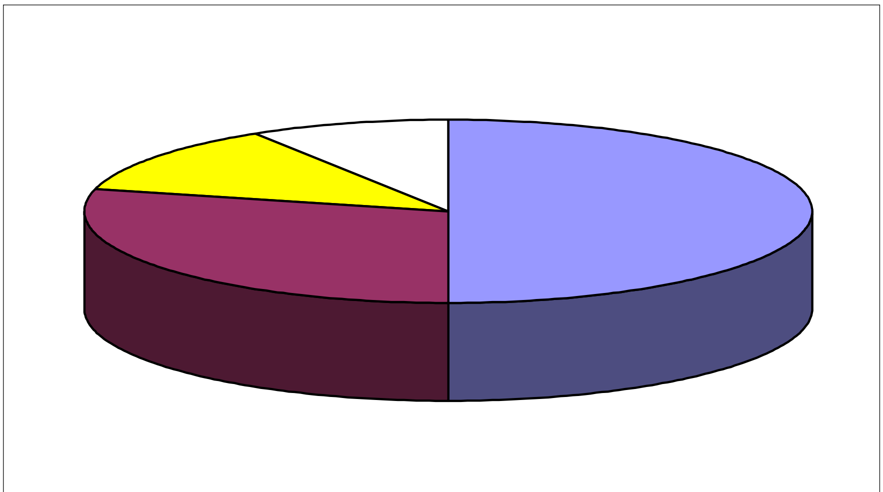

Figure 1: **Proportion of epidemics of spring barley diseases in 320 fields of the State Variety Trials (Czech Republic, 1989-2000)**

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of this crop and later, volunteer plants of spring barley allow to bridge the summer season, i.e. the time when neither spring nor winter barley is grown.

Leaf rust importance and harmfulness

Leaf rust of barley has become more important particularly in several past decades (DREISEITL, 1988a). It is mainly due to changed properties of cultivars, in particular the morphotype (BOUMA, 1967), and apparently their lower partial resistance to leaf rust, resistance to powdery mildew (BRÜCKNER, 1970) and application of increased rates of fertilizers. In the Czech Republic, the increase in leaf rust occurrence was caused particularly by renaissance of growing winter barley. Its proportion of total barley area being less than 3 % in 1965-1978 (at minimum below 1 % in 1975) has considerably increased and since 1984 its area ranges around 30 %.

Harmfulness of leaf rust is often underestimated because barley is usually infected at the end of the growing season. However, GRIFFEY et al. (1994) found that natural epidemics of leaf rust decreased grain yield of the susceptible winter barley cultivar 'Barsoy' by 32 %. In our trials, grain yield of the spring barley cultivar 'Krystal' was 25 % lower due to leaf rust infection. The lower 1000-grain weight, however, resulted in reduced yield of plump grain used for malting (>2.5 mm) by almost 30 % (DREISEITL, 1987a). Moreover, this grain, harvested from infected plots and screened on 2.5-mm sieve, had worse parameters of malting quality, and namely lower extract content in malt dry matter and lower relative extract (DREISEITL, 1987b).

Yield loss and lower quality of barley grain caused by leaf rust can be avoided by application of fungicides or growing resistant cultivars. However, fungicide application against leaf rust is difficult because of a short period between treatment need and harvest.

Breeding resistant cultivars

Breeding resistant cultivars, similarly to powdery mildew, has appeared as the most applicable way. The first cultivar with purposefully incorporated gene for resistance to leaf rust (*Rph3*) was 'Karat' (BRÜCKNER, 1982). In 1985, first symptoms of infection were found on cultivars possessing this gene, and in 1988, they were attacked by leaf rust similarly to susceptible cultivars (DREISEITL, 1990). At that time, there were already available pre-bred lines of spring barley derived from other sources of resistance and breeders focused mostly on using the gene *Rph7* (DREISEITL, 1988b). That resulted in development of the Czech spring barley cultivar 'Heris' which was registered in 1998. 'Heris', as one of the first European cultivars, carries the gene *Rph7* (DREISEITL and STEFFENSON, 2000) together with the gene *mlo* for resistance to powdery mildew (DREISEITL and JØRGENSEN, 2000). It exhibits resistance to net blotch (*Pyrenophora teres*), leaf scald (*Rhynchosporium secalis*) and to barley yellow dwarf virus (DREISEITL and SVACINA, 2001). 'Heris' was also used in the development of one of two molecular markers found until now for detection of the gene *Rph7* (BRUENNER et al., 2000; GRANER et al., 2000).

Table 1: **Leaf rust resistance (PR) genes in selected Czech and Slovak spring barley cultivars**

Cultivar	Registration	PR genes*	Cultivar	Registration	PR genes*
Akcent	1992	*Rph12*	Krystal	1981-2000	*Rph2*
Amos	1995	*Rph4*	Maridol	1999	*Rph3,Rph12*
Amulet	1995	*Rph3,Rph12*	Olbram	1996	*Rph12*
Atribut	1996	*Rph3,Rph12*	Pejas	1996	*Rph12+none*
Expres	1999	*Rph12+none*	Primus	1995	*Rph2*
Forum	1993	*Rph3*	Rapid	1976-1983	*Rph2,Rph4*
Heris	1998	*Rph7*	Rubin	1982-2000	*Rph12*
Karat	1981-1989	*Rph3*	Tolar	1997	*Rph12*
Kompakt	1995	*Rph3,Rph12*	Viktor	1994	*Rph3+none*

* DREISEITL and STEFFENSON, 2000

Virulence for the gene *Rph7* was first detected in Israel (GOLAN et al., 1979) and Morocco (PARLEVLIET et al., 1981). Leaf rust epidemics in 1990 terminated the effectiveness of the gene *Rph7* in the USA (STEFFENSON and JIN, 1993). Virulent pathotypes caused yield loss of barley even in cultivars possessing the gene *Rph7* (GRIFFEY et al. 1994). Such cultivars had been developed in Virginia and were grown there since 1968 (STEFFENSON and JIN, 1993). In Europe, the virulence *Vph7* has not been found until now, therefore the resistance governed by the gene *Rph7* is still fully effective. Beside *Rph3* and *Rph7*, Czech and Slovak spring barley cultivars possess some additional genes for resistance to leaf rust, namely *Rph12* (*Table 1*). However, effectiveness of all of these genes against the current pathogen population is (except for *Rph7*) of minimum importance.

Sources of resistance

Breeding barley for resistance to leaf rust was limited until recently by a lower number of known sources. The situation, however, has changed during the past years. YAHYAOUI et al. (1988) have found four new sources of resistance in barley land race cultivars from Ethiopia, JIN et al. (1996) have described new genes *Rph13* and *Rph14*, and BROOKS et al. (2000) have detected a recessive gene against leaf rust of barley. All of these sources originate from *H. vulgare* accessions.

The two last described genes, *Rph15* (CHICAIZA et al., 1996; FRANCKOWIAK et al., 1997) and *Rph16* (IVANDIC et al., 1998), similarly to genes *Rph10* and *Rph11* (FEUERSTEIN et al., 1990) originate from wild barley (*H. vulgare* ssp. *spontaneum*). Just wild barley is undoubtedly a significant reservoir in which a large number of potential sources of resistance to leaf rust have been found (MANISTERSKI et al., 1986; MOSEMAN et al., 1990; JIN and STEFFENSON, 1994; JIN et al., 1995; MANISTERSKI and ANIKSTER, 1995). At present, we are engaged in search for and use of new resistance sources of wild barley to powdery mildew (DREISEITL and BOCKELMAN, 2000). We suppose to screen such a rich collection of these new sources also for resistance to leaf rust.

A promising resistance source of barley to leaf rust, as well as to other diseases, is *Hordeum bulbosum* (PICKERING et al., 1998; WALTHER et al., 2000). In our institute, we study several tens of derivatives from *Hordeum bulbosum* that exhibit resistance to leaf rust and powdery mildew (PICKERING, personal communication). It is assumed that the importance of this species for resistance of barley cultivars to diseases will increase in the future.

In addition to the mentioned sources of hypersensitive (posthaustorial) resistance, practical use of nonhypersensitive (prehaustorial) resistance of barley to leaf rust can be much more seriously considered (PARLEVLIET, 1976; DREISEITL, 1982; FEKADU ALEMAYEHU and PARLEVLIET, 1996; HOOGKAMP et al., 1998).

Conclusion

Knowledge gained from many host-pathogen systems suggests that it is usually difficult to reach sufficient durability of varietal resistance by either purposeful combining suitable hypersensitive resistances or using prehaustorial (multigenic) resistance. A present level of molecular biology and anticipated development of its applications provide new possibilities of achieving further findings and their consecutive use for obtaining more durable varietal resistance regardless it is based on either prehaustorial or posthaustorial resistance (BOROVKOVA et al., 1997, 1998; BRUENNER et al., 2000; GRANER et al., 2000; IVANDIC et al., 1998; QI et al., 1999; STEFFENSON, 1995).

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