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Drought and root system size of barley and wheat

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Zusammenfassung

Kornertrag von verschiedenen Sommergerste- und Winterweizen-Sorten in umfangreichen Feldversuchen wurde mit ihrer Wurzelsystemgröße (WSG) von zwei Standorten im trockenen Jahr 2007 verglichen. Die Ertragsunterschiede wurden mit publizierten Angaben für spezifischen Wasserverbrauch an Einheit von Kornertrag konfrontiert. So wurde gefunden, dass ein Drittel Gerstensorten mit überdurchschnittlicher WSG im Vergleich mit dem Drittel mit unterdurchschnittlicher WSG nutzte um 14% mehr Bodenwasser vom Totalverbrauch in Gerste und um 2% mehr in Weizen. Aber wenn Weizen wurde spät gesät, es wurde schon 5%.

Schlagwörter: Trockenheit, Gerste, Weizen, Wurzelsystemgröße, Kornertrag, Stärke, Wasserverbrauch

Summary

Grain yield of different varieties of spring barley and of winter wheat in extensive field trials was compared with their root system size (RSS) on two locations in dry year 2007. The differences in yield were related to the published data about water consumption for a unit of grain yield. It was found that one third of barley varieties with above-averaged RSS as compared to the third one with under-averaged RSS used by 14% more of soil water of the total demand for barley and by 2% for wheat. However, in stress due to late sowing it was 5% in wheat.

Keywords: Drought, barley, wheat, root system size, grain yield, starch, water consumption

Material and methods

We evaluated about 20 varieties of spring barley in 2005-2008 and similar number of winter wheat in 2007-2010 for their root system size (RSS) on two locations in three terms (elongation, heading and grain filling) and the values compared with yield and quality results in official variety trials on about 20 locations. The trials were evaluated on low and high input level.

Results

Significant relationship between RSS and yield was found only in extremely dry year 2007 in both crops (for barley r^2 = 0.230* and 0.221*, for wheat r^2 = 0.285* and 0.284*, in both input levels respectively). In other years was the relationship found only in some environments in both crops. In wheat was the relationship however also significantly negative in 2008, the highest-yielding year, at the three stations at the lowest altitude and with the highest temperature (r^2 = -0.459*). In both crops was not significant yield difference between groups of varieties with average and above-average RSS, but significant between group with under-averaged and averaged RSS.

Discussion

In both crops was in the dry year 2007 significantly higher content or yield of starch in grain (with content in barley r^2 = 0.403**, with yield in barley r^2 = 0.694**, in wheat r^2 = 0.248*) in varieties with greater RSS. A reduction in barley grain weight has been found to be greater under heat stress (average 13%) than under drought (6%). Under these conditions, the amount and quality of starch was reduced, especially when stresses occurred during grain filling (SAVIN and NICOLAS 1999). In our experiments decreased the yield in 2007 in comparison to all four experimental years by 14% (CHLOUPEK et al. 2010). A single 25-mm irrigation in the early stages of grain filling increased the malt extract in barley (PAYNTER and YOUNG 2004). This effect of irrigation on starch concentration and yield was similar to the effect of a greater RSS, as described in 2007.

The quality of harvested barley grain was evaluated from four stations. Two stations are located at lower altitudes (260 and 425 m, respectively) than the other two (450 and 505 m, respectively). They have lower average precipitation (555 and 481 mm vs. 616 and 594 mm, respectively) and higher average annual temperatures (8.9 and 8.0°C vs. 7.4 and 7.5°C). Official evaluation of all 51 varieties and candivars[1] in the experiments (not all were evaluated for RSS) showed lower starch contents in the grain grown at the drier stations (66.9 and 68.4%) than in the grain from wetter ones (71.2 and 69.8%). It can be concluded that drought showed a similar effect as small RSS on the starch content of the barley grain, which was lower (CHLOUPEK et al. 2010).

The crop water requirement (CWP) for winter wheat was about 430 mm. Optimal irrigation amounted to 186, 161 and 99 mm for winter wheat in dry, normal and wet seasons, respectively (SUN et al. 2010). The CWP of irrigated wheat was lower; 1.09 (0.6-1.7) kg m^{-3} (ZWART and BASTIANSSEN 2004).

[1] Candivar = candidate for variety or cultivar

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Our results showed that wheat varieties with a 21% greater RSS had a 420 kg ha^{-1} increase in grain yield in 2007 (STŘEDA et al., unpublished yet); based on the data of KIRKEGAARD et al. (2007), this increase corresponds to the use of approximately 7 mm of additional subsoil water (420/59), i.e. about 2% of total demand as published by MARTYNIAK (2008) for Central Europe (7/314). However, comparison of the varieties with the smallest and greatest RSSs (*Ilias* and *Etela*) showed yield difference of 860 kg, i.e., about 15 mm of subsoil water, i.e. 5% (15/314). This difference shows selection perspectives for the better use of subsoil water in dry years. When wheat was sown late in 2007, a similar comparison between the groups with below- and above-average RSSs shows a difference in yield of 950 kg ha^{-1}, corresponding to the use of an additional 16 mm of subsoil water in this dry year. The difference corresponds also to 5% (16/314) of total demand as published by MARTYNIAK (2008).

Similarly calculated in wheat according to publication by KIRKEGAARD et al. (2007) who published 59 kg of wheat grain/mm of soil water it would be responsible for about 5 mm of water. Spring barley needs 293 mm of soil water during its vegetation (MARTYNIAK 2008). When we use the data by PELTONEN et al. (2011), the 9.5% of *barley* RSS increment (CHLOUPEK et al. 2010) would be accounted for 40 from 293 mm, i.e. for about 14% of the total demand or, for 40 mm from -145 mm seasonal deficit i.e. for about 27% of it.

The highest values of water requirements of plants were observed in the stages from shooting to heading, during the intensive increase of biomasses. During this period, the plants utilized up to 5 mm of water per day. Seasonal deficits of precipitation during the growing season in central Poland were -145 and -169 mm for barley and wheat, respectively. In the growing season they utilized from 293 to 314 mm of soil water (MARTYNIAK 2008).

CHLOUPEK et al. (2010) compared yield of seven barley varieties with under-averaged RSS with yield of six varieties with averaged RSS of all 20 evaluated varieties in dry year 2007, when the yield of four standard varieties was only 5.62 t/ha, but in other three years averaged to 6.82 t/ha due to drought during vegetation. The varieties with under-averaged RSS yielded 4.87 t/ha but the ones with averaged RSS 5.19 t/ha. The difference amounted to 320 kg/ha due to greater RSS by 9.5% (1.48 and 1.62 nF, respectively). Spring cereals decreased yields by 45-75 kg/ha due to decreased precipitation by 10 mm (PELTONEN et al. 2011). The difference in the RSS responded therefore for about 40 mm higher precipitation (320 kg/75 kg) in the dry year.

Conclusion

In dry year 2007 brought varieties with smaller RSS significantly lower yield of both cereals in comparison with varieties with greater RSS. Already during selection should be such lines eliminated. However, also one-sided selection for great RSS should be avoided, since in particular winter wheat (which has greater RSS in comparison with spring barley) varieties with great RSS could bring in moist years lower yields.

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