DISTRIBUTION OF BARLEY ROOT BIOMASS IN SOIL PROFILE

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ABSTRACT

In 2010 and 2011 was realized a field trial with selected varieties of barley in two localities, Hrubčice and Želešice. In five varieties root system size, its distribution in soil profile layers within 60 cms of depth and grain yield were evaluated. The impact of locality, year and variety on root system attributes was quantified. The amount of root biomass was always influenced significantly by year (up to 43.5%), locality (up to 19.5%) and their mutual interaction. The impact of these factors differed according to the depth of soil profile. In deeper depths the effect of variety also developed. In 2011 statistically significantly higher values of root length density (RLD) were identified in all localities. In shallow layers of soil plants produced more roots in Želešice. Highest values of RLD were determined in the layer of 0 to 10 cm. Tendency to increase RLD in both localities and most varieties in layer of 40 to 60 cm were detected. A significant dependency of grain yield on RLD was only determined in middle layers of the soil profile. In wet year of 2010 a significant negative correlation was determined. A positive relation was recorded in 2011.

Key words: barley, root length density, root system, yield, soil profile

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INTRODUCTION

In natural conditions reachable yield of cereal crops is limited by many factors – the accessibility of water and nutrients in soil, diseases and pest stress, the course of weather. Various strategies of adverse conditions resilience in the course of yield production in plants are often connected with specific ways of root system production, its qualitative and quantitative parameters. These parameters include length, surface, weight and the architecture of root system – branching, intensity and layout of root length density in soil and root lifespan. Differences show on the level of types but it is possible to anticipate them in varieties, too (Fitter A. 2002).

The aim of this paper is to evaluate the differences in root biomass production and the intensity of root length density in various soil profile layers and to interpret the relationship between the given features and grain yield in selected varieties of spring barley.

MATERIAL AND METHODS

The field trial was realized with selected varieties of spring barley (*Hordeum vulgare* L.) in two localities, Hrubčice and Želešice (Moravia, Czech Republic) in 2010 and 2011. In five varieties – Aksamit, Blaník, Aktiv, Bojos and Radegast – root system size and its distribution in soil profile layers up to 60 cm deep was evaluated. One representative plant from each variety was always selected for analysis in each locality. Soil and roots were sampled by the soil-core method (Böhm W. 1979) in the phase of grain filling (BBCH70). The samples were then scanned and processed by WinRHIZO software (Régent Instruments Inc.). For individual layers root length was analysed and root length density – RLD [cm.cm^{-3}] per soil unit was determined and compared to the yield of the given varieties at the site of ÚKZÚZ Hrubčice and Chrlice. A variance analysis with subsequent Tukey LSD test and a correlation analysis were performed (software STATISTICA, ver. 10).

RESULTS AND DISCUSSION

Hrubčice and Želešice 2010

In 2010 the barley root system in Hrubčice was monitored in all layers of the soil profile (0 – 60 cm). The largest amount of roots was located in the upper soil layer 20 cm deep (52 – 80%). High values of RLD in shallow soil layers are typical of cereal crops and grasses (Gregory P. 2006). In cereal crops RLD reaches 2 – 10 cm.cm^{-3} (Manske G.G.B., Vlek, P.L.G., 2002). On average 45% of the root system in monitored varieties (6 cm.cm^{-3}) was located within the layer of 0 – 10 cm. Zuo *et al.* (2004) found lower RLD values for wheat in a shallow soil layer to a depth of 10 cm. In the layer of 10 – 20 cm on average 20% roots were detected. The downward tendency in RLD values persisted into the layer of 30 – 40 cm where only 3 – 8% roots were located. In further layers (40 – 60 cm) more roots (22% on average) abounded in most varieties. The pattern of RLD shows increasing tendencies with an ever-deeper soil profile in this location. This increasing of RLD in deeper soil layers (50 cm) for maize discovered Kirkham M.B. *et al.* (1998). Lampurlanés J.*et al.* (2001) reported higher RLD of spring barley in the soil layer of 50 – 75 cm during the flowering. RLD in all soil profile layers within the depth of 60 cm in 2010 are described in Figure 1. In Želešice the greatest part of the root system was also located in the layer of 0 – 10 cm (63%). Plants produced on average 18% more root biomass compared to the locality of Hrubčice. In all deeper layers RLD values were inferior to those in Hrubčice. The least amount of roots was determined in the layer of 20 – 50 cm (only 4% roots in all 10 cm-layers of the profile). In the layer of 50 – 60 cm only a slight increase in biomass was detected. Average RLD values in individual soil profile layers confirm more intensive root system production in shallow layers in Želešice.

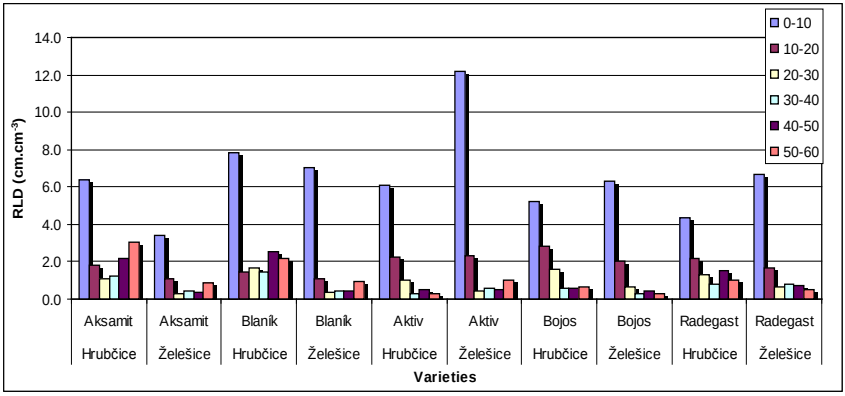

Fig. 1: RLD values in all soil profile layers in Hrubčice and Želešice in 2010.

In Želešice RLD values were 20% higher only in the layer of 0 – 10 cm. In other layers more root biomass was always detected in Hrubčice (in the layer of 10 – 20 cm by 23% more, but in 40 – 50 cm by up to 69% more). Selected varieties differed greatly in the absolute amount of produced root biomass. Highest RLD of the varieties Aksamit and Blaník in Hrubčice was detected. In Želešice these varieties produced minimum root length density compared both to other varieties and the Hrubčice. The generally smaller RLD values in Želešice are caused by a lesser amount of root biomass produced in deeper layers (20 – 60 cm) where only 20% roots were located (38% in Hrubčice).

Hrubčice and Želešice 2011

In 2011 similar behaviour of the root system was recorded in Hrubčice as in 2010. In the top layer of 0 – 10 cm on average 46.3% of total root biomass were located. The layers of 30 – 40 cm and 40 – 50 cm feature 7.6 and 9% of all roots. In the layer of 50 – 60 cm some varieties increased the amount of RLD slightly again. The percentage representation of root biomass in soil profile layers is shown in table 1.

Tab. 1: Percentage representation of root amount in soil profile layers.

Soil depth	Hrubčice 2010	Želešice 2010	Hrubčice 2011	Želešice 2011
0 – 10 cm	45.7%	63.0%	46.3%	60.2%
10 – 20 cm	17.1%	15.0%	14.6%	8.5%
20 – 30 cm	10.0%	4.6%	12.6%	8.5%
30 – 40 cm	6.3%	4.9%	7.6%	7.9%
40 – 50 cm	10.5%	4.7%	9.0%	7.4%
50 – 60 cm	10.0%	7.2%	10.0%	7.5%

The total amount of roots in relatively dry year 2011 is statistically significantly higher than in 2010 ($P \leq 0.05$). This case is in agreement with results by Hamblin A. *et al.* (1990). In rain-fed wheat, RLD are much higher in drier years than in humid ones. The depth of 0 – 20 cm featured 61% roots. Average RLD values of 2011 differed minimally from the results of 2010, however no great variation in RLD among varieties was recorded as it had been in 2010. In 2011 in Želešice in the layer of 0 – 10 cm the average recorded RLD was 60% of the total root biomass (48% Aktiv, 65% Blaník). This amount is different than RLD in 2010 (63%) and in 2011 in Hrubčice (46 %). The high RLD ratio in this layer compared to the whole is caused by quite low but level RLD values in deeper layers (see Tab. 1).

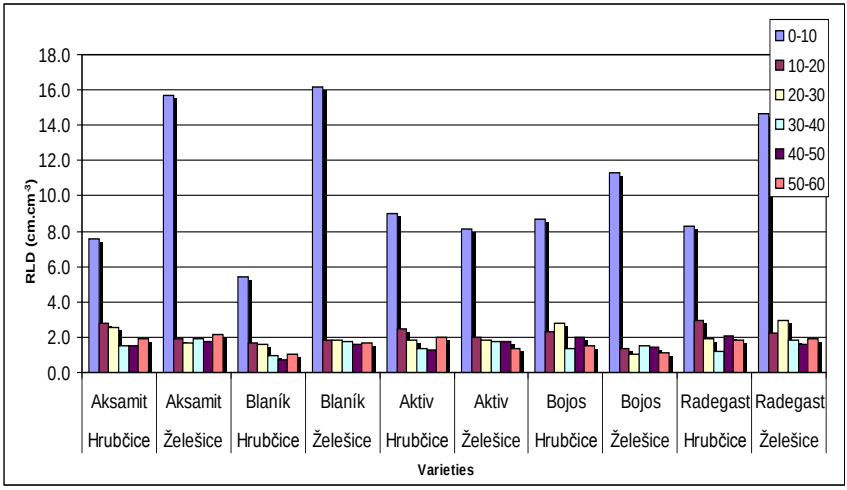

Fig. 2: Root length density values in monitored varieties in all soil profile layers to 60 cm deep in the localities of Hrubčice and Želešice in 2011.

In 2011 in Želešice it is possible to observe more balanced root length density both among varieties and among soil profile layers. The absolute RLD values vary mostly in shallow layers between 8.1 – 16.2 $cm.cm^{-3}$. These data exceed typical values for cereal crops considerably. RLD in Hrubčice varied from 5.5 – 9.0 $cm.cm^{-3}$. The root length density in all soil profile layers to 60 cm of depth in Hrubčice and Želešice in 2011 is described in figure 2. RLD values in varieties in all soil profiles (0 – 60 cm) in 2011 show different behaviour of varieties in specific environments. The greatest RLD was recorded in the varieties of Aksamit and Blaník in Želešice, but lowest in Hrubčice. Similar behaviour was recorded in these varieties in 2010, too, when they adapted the production of roots according to the locality. Thus Aksamit gave one of the highest yields in all localities. Brown S.C. *et al.* (1987) investigated the effect of locality and variety on grain yield of two barley cultivars. Variety, which achieved higher grain yield, created significantly more roots in deeper soil layers to 15 cm. Similar behavior was observed in the variety Aksamit at the site Želešice. The highest RLD values in the layer of 0 – 10 cm were detected in all profiles in both localities, in 2010 and 2011. Higher RLD was observed in both localities in all layers in 2011 (a statistically significant impact of the year). Lesser differences in RLD in a locality were detected in both years in Hrubčice. RLD in Želešice is more varied in 2010 and 2011, thus is year dependent. Lesser variety differences in root length density are obvious in Hrubčice.

RLD and grain yield correlation

In 2010 grain yield was always higher in Chrlice – a comparative locality to Želešice (by approximately 20% higher). An average RLD in this locality was lower in all varieties. In the wet year 2010 greater root system production proved more a negative attribute that influenced grain yield adversely. In 2011 plant production was greater in Hrubčice (2 – 9%). However grain yield in both localities was comparable. In 2011 RLD took a rather different effect within the impact of variety than locality. In 2010 grain yield was lesser in both localities compared to grain yield in the same localities in 2011. A significant relation between grain yield and root length density was detected in a deeper layer of 20 – 60 cm throughout localities in the wet year of 2010 in particular. A negative relation of monitored parameters was confirmed in the layer of 30 – 40 cm (r = -0.87*) and 40 – 50 cm (r = -0.91*). In the relatively dry year of 2011 a positive relation between grain yield and RDL in 20 – 30 cm (r = 0.88*), 30 – 40 cm (r = 0.87*) and 40 – 50 cm (r = 0.98*) was

confirmed. In a shallow layer was not found statistically significant relationship, however Manske G.G.B., Vlek, P.L.G. (2002) found a negative correlation between RLD and grain yield of wheat (r = -0.70 **). It is possible to consider grain yield production limited by root biomass production a very variable plant attribute that is linked to the strategy of reaction to different soil moisture conditions. Plasticity of the root system is its most important feature for adaptation to the requirements of the environment (Fitter A. 2002).

*Tab. 2: Impact of monitored factors and their interactions (%) on RLD values in selected depths of soil profile (*Statistically significant values (P ≤ 0,05).*

Factor	0 – 20 cm	20 – 40 cm	40 – 60 cm	0 – 60 cm
Locality	19.4*	11.8*	16.1*	16.1
Year	29.9*	43.5*	23.1*	23.1*
Variety	2.9	4.3	10.2*	10.2
Locality × year	14.8*	16.0*	18.2*	18.2*
Locality × variety	4.9	8.0*	6.1	6.1
Year × variety	10.1*	4.8	10.5*	10.5

Average RLD values in all soil profile (0 – 60 cm) were mostly affected by year (23.1%) and the interaction of locality × year (18.2%) and variety × year (10.5%). A statistically significantly lesser root length density was determined in 2010 compared to 2011. In 2011 RLD of varieties in Želešice differed significantly from other variants. RLD values in Hrubčice were not significantly different in either year. In 2010 RLD of the Bojos, Radegast and Aksamit varieties differed significantly from the RLD values of Radegast and Aksamit in 2011. Impact of all monitored factors and their interactions showed in all layers of the soil profile (Tab. 2). In 2011 plants produced statistically significantly more roots in all layers. In the wet year 2010 we can assume it was not necessary for plants to produce a vast root biomass to get the optimal amount of nutrients and water. In both monitored years a statistically significantly greater amount of roots were detected in Želešice in 0 – 20 cm (only shallow soil cultivation, more humid locality). In deeper layers greater RLD was determined in the more fertile but drier locality of Hrubčice. An impact of a variety on RLD was only significant in the layer of 40 – 60 cm when variety Aksamit produced a significantly greater amount of roots than Aktiv and Bojos. The effect of a variety interacted in most layers with the effect of year in particular and locality in one case. Based on the results of the variance analysis we can deduce variety differences in the strategy of root system production when Aksamit and Radegast in particular proved as plastic varieties in both years (significantly different RLD values). In contrast varieties Bojos and Blaník produced mostly the same amount of roots in given layers of the soil profile.

CONCLUSIONS

Distribution of root system size in soil profile and grain yield in five varieties,of spring barley were evaluated. The effect of locality, year and variety on the given root system features was quantified. The amount of root biomass was always significantly affected by year (by up to 43.5%), locality (by up to 19.5%) and their mutual interaction. The influence of these factors differed in dependence of the soil profile depth. In deeper layers variety effect also showed. In 2011 statistically significantly higher root length density values were determined in all localities. Plants in Želešice produced more roots in the shallow soil layer. The highest values of RLD were identified in the layer of 0 – 10 cm. A significant dependency of grain yield on root length density was determined only in the middle layers of the soil profile. In the wet year 2010 a significant negative correlation was established. A positive relation was discovered in 2011.

REFERENCES

BÖHM, W.,1979: *Methods of Studying Root Systems*. Springer.Berlin,188 p. ISBN 3-540-09329-X.

BROWN, S.C., KEATINGE, J.D.H., GREGORY, P.J.,. COOPER, P.J.M., 1987: Effects of fertilizer, variety and location on barley production under rainfed conditions in Northern Syria I. Root and shoot growth. *Field Crops Research*,16: 53 – 66.

FITTER, A., 2002: *Charakteristics and functions of root systems*. p. 15 – 32. In: Waisel, Y., Eshel, A., Kafkafi, U. (ed.): Plant roots: The hidden half. Marcel Dekker Inc., New York, 1120 p. ISBN:0-8247-0631-5.

GREGORY, P., 2006: *Plant roots, growth, activity and interaction with soils*. Blackwell Publishing, Oxford, 318 p. ISBN 1-4051-1906-3.

HAMBLIN, A., TENNANT, D., PERRY, M. W. 1990: The cost of stress: dry matter partitioning changes with seasonal supply of water and nitrogen to dryland wheat, *Plant and Soil*. 122: 47–58.

KIRKHAM, M.B., GRECU, S.J., KANEMASU, E.T.,1998: Comparison of minirhizotrons and the soil-water-depletion method to determine maize and soybean root length and depth, *European Journal of Agronomy*, 8: 117 – 125.

LAMPURLANÉS, J., ANGÁS, P., CANTERO-MARTÍNEZ C., 2001: Root growth, soil water content and yield of barley under different tillage systems on two soils in semiarid conditions. *Field Crops Research* 69: 27 – 40.

MANSKE, G.G.B., VLEK, P.L.G., 2002: *Root architekture – Wheat as o model plant*. p. 249 – 260. In: Waisel, Y., Eshel, A., Kafkafi, U. (ed.): Plant roots: The hidden half. Marcel Dekker Inc., New York, 1120 p. ISBN:0-8247-0631-5.

ZUO, Q., JIE, F., ZHANG, R., MENG, L., 2004: A Generalized function of wheat's root length density distributions. *Vadose Zone Journal* 3: 271–277.