Introduction

An influence of plant species on nitrogen (N) management is obvious. The plants of the family Brassicaceae (Cruciferae) belong to high consumers of N for biomass production. They receive more N than cereals or legumes (SMUKALSKI et al. 1991). Although the root density of Brassicaceae is lower than e.g. Poaceae, their root system grows faster and achieves greater depths (MEISINGER et al. 1991). This allows access to a greater volume of soil and reduces N leaching (THORUP-KRISTENSEN 2001). BODNER et al. (2011) found a higher root biomass production of white mustard (Sinapis alba L.) compared to lacy phacelia, rye and vetch. The ability of mustard to immobilize N was evaluated by FRANCIS et al. (1998). Similarly, HERRERA and LIEDGENS (2009) compared mustard with other cover crops. White mustard in comparison with sunflower and lacy phacelia showed the smallest N loss by washing but was not absorbing most N from the soil. The reason may be its rapid initial growth. Flowering stage starts early, therefore, total N accumulation is lower and its retention time is shorter.

Material and methods

The experiment was conducted at two Czech locations in 2010 and 2011. The first location Horní Třešňovec is located in the foothills of Orlické hory mountains and represents less fertile soils with higher annual rainfall and lower average air temperature (temperate warm agroclimatological area; KURPELOVÁ et al. 1975). Soils are stagnosols with topsoil of 30 cm. The second location Troubsko is located in the fertile area near Brno in the warm and mainly dry agroclimatological area (KURPELOVÁ et al. 1975). Soils are fluvisols.

Eight varieties of white mustard, i.e. Medicus, Seco, Semper, Severka, Sito, Sirte, Veronika and Zlata were evaluated. Plants were planted in small plots experiment with four replications. At the beginning and end of the experiment soil samples were collected. The content of NO$_3^-$ and NH$_4^+$ nitrogen was determined.

Root system size (RSS) was measured by two methods: electrical capacity (CHLOUPEK 1977) and digital image analysis. The first method is nondestructive and is performed directly in an environment where the plant grows (in situ). The measuring device operates with two electrodes, the cathode (forceps or needle) is attached to the stem of plants about 1 cm above soil surface. Anode (needle) is inserted into the soil at a distance of 10 cm from the studied plants. The electric current passes through the circuit at a frequency of 1 kHz. The measured values are given nF (nanofarad). The instrument measures the parallel capacity (Cp) in a similar way as capacitors. In this case, the capacitor plates is a root system and the substrate in which it grows. Measurements were performed by Voltcraft LCR 4080.
sensor in three growth stages (stem elongation, flowering and ripening). Ten plants of each variety in each replication were measured.

The second method is based on digital analysis of washed and scanned roots (STŘEDA et al. 2009). Sampling of soil with the root system was carried out at the end of the experiment in the growth phase of ripening. The sampling probe had a diameter of 63 mm and sampling was conducted to a soil depth of 60 cm. The obtained soil block was divided into 6 parts with a length of 10 cm, frozen at -20°C and stored for further processing. After thawing the block was floated through a system of sieves with mesh diameters of 1.6 and 0.6 mm. Captured roots were collected and subsequently scanned. The scanned image was processed in the program WinRhizo, Basic version (Régent Instruments Inc., Québec). This program evaluates among others the total length and surface roots. Scanned roots were then dried and weighed. The data was used for calculation of RLD (Root Length Density), RSD (Root Surface Density), which describe the length respectively area of roots per unit volume of soil. Furthermore, SRL (Specific Root Length), which evaluates the length of roots per gram root mass was evaluated. Aboveground biomass (dry weight) was determined at seed maturity (BBCH 70). The data were statistically processed wit Statistica, Vers. 9 (StatSoft, Inc., Tulsa, OK). Mean comparisons within analysis of variance was carried out by Fisher’s LSD test (α=0.05).

Results and discussion

RSS of single varieties on both localities in both years is displayed in Figure 1. Underdeveloped root system was observed in Třešňovec in 2010 which was most probably caused by extremely wet and rainy weather during the vegetation period. Thereby, the soil was wet for a considerable time and roots did not have enough air to evolve well. Varieties Medicus and Seco showed a smaller root system at both localities and years, whereas Semper showed a big root system in each environment which could be explained by a strong genetic effect. This fact is also shown in Figure 2, where the influence of locations and year on electrical capacity is illustrated. Mean comparisons from the analyses of variances are demonstrated in Table 1.

Further an influence of RSS on soil NO\textsubscript{3} nitrogen consumption was observed. In Třešňovec in both years and in Troubsko in 2011 the varieties with higher RSS had a lower NO\textsubscript{3} nitrogen balance in soil than varieties with larger root system. In Troubsko in 2010 a conclusive negative correlation between RSS and content of NH\textsubscript{4} ions in the soil (r=-0.81*) was observed. Influence of RSS on biomass production was not statistically conclusive. Aboveground biomass showed an irresolute positive correlation to NO\textsubscript{3} content in the soil at the end of vegetation period (r=0.54).

Using digital analysis SRL was determined, which is an important root system character and expresses the length of roots per unit of root system weight. Varieties with smaller

![Figure 1: Genotypic variability of Root system size (RSS) in dependence of location and year (mean values from 3 measurements)](image1)

![Figure 2: Variability of root system size (RSS) according to environments (means over all tested varieties)](image2)
SRL had higher RSS (higher electrical capacity) and lower NO$_3^-$ nitrogen balance in the soil at the end of vegetation. Rather surprising was that varieties with a shorter and heavier root system had higher electrical capacity. Medicus had the highest electrical capacity on both locations in 2010 but showed second lowest RSS in Třešňovec in 2010, whereas it showed the highest SRL (six times higher than three varieties with the lowest SRL and two times higher than Veronika, the variety with the second highest SRL) (Figure 3). In Troubsko the genotypic difference in SRL was not so significant. Medicus showed four times higher values of SRL compared to the two varieties with the lowest SRL.

In Figure 4 a generally higher specific root length can be seen for Třešňovec which could be explained by a lower soil fertility, especially NO$_3^-$ nitrogen, which was washed out as a result of long-term soil waterlogging. Waterlogging itself can also have significant influence on root system development, when plants are stressed by lack of air. The above mentioned specific characteristics of Třešňovec in 2010 (lower topsoil profile, little water-permeable subsoil layer, less fertile soil, long-term waterlogging) could explain the statistically significant difference between RLD 0-20 cm and RLD 0-40 cm ($r=-0.77^*$). It is probably the result of different strategies of the varieties in regard to root system development.

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References
THORUP-KRISTENSEN A, 2001: Are differences in root growth of nitrogen catch crops important for their ability to reduce soil nitrate-N content, and how can this be measured? Plant Soil 230: 185-195.

Note: The online version of the proceedings includes all figures in colour. It can be downloaded either from the homepage of the meeting (http://www.raumberg-gumpenstein.at/ Downloads - Fachveranstaltungen/Tagungen - Saatzüchtetagung - Saatzüchtetagung 2011) or requested from the corresponding author.