Lehr- und Forschungszentrum für Landwirtschaft
Raumberg-Gumpenstein

62. Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs 2011, 105 – 108
ISBN: 978-3-902559-74-6

Biomass production of white mustard (*Sinapis alba* L.) varieties in relation to the root system size

Martin Hajzler[1*], Jana Klimešová and Tomáš Středa

Abstract

Root system size (RSS) of eight white mustard varieties was evaluated in a field trial. The two-year experiment was conducted on two different agro-ecological sites in the Czech Republic: Troubsko and Horní Třešňovec. RSS was measured during the vegetation period by the electrical capacity method. At the end of vegetation the above ground biomass and root samples were evaluated by digital image analysis. There was no statistically significant relationship between RSS and amount of aboveground biomass. Relationship between RSS and content of NO_3^- and NH_4^+ ions in the soil after harvest was observed. RSS negatively correlated with the content of nitrate nitrogen in the soil, however, the correlation was statistically not significant. Evaluation across sites revealed a positive correlation between aboveground biomass and amount of residual NO_3^- ions in the soil (r=0.54). On the other hand a significant negative correlation (r=-0.81) of RSS and NH_4^+ ions content was observed in Troubsko.

Keywords

Biomass, cover crops, electric capacity, nitrogen, root system, *Sinapis alba*

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. CONSTANTINE et al. (2010) studied the effect of long-term cultivation of mustard on N leaching and mineralization rate of residual N. The constant efficiency of mustard to prevent leaching of soil N was recorded in long-term (17 years) observations. However, only in the early years of the experiment, the influence on increasing the mineralization of N in the soil was registered.

Aims of this work were the following: (i) analysis of different N intake from the soil, aboveground biomass production and the root system size of eight white mustard varieties, (ii) to analyze whether plants with larger root system uptake more soil N, (iii) to determine the correlation between amount of aboveground biomass and the amount of residual N in the soil.

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

---

[1] Mendel University, Department of Crop Science, Breeding and Plant Medicine, Zemědělská 1, CZ-613 00 BRNO

[*] Ansprechpartner: Martin HAJZLER, martin.hajzler@mendelu.cz

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 detemined 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 diplayed 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$_3^-$ nitrogen consumption was observed. In Třešňovec in both years and in Troubsko in 2011 the varieties with higher RSS had a lower NO$_3^-$ nitrogen balance in soil than varieties with larger root system. In Troubsko in 2010 a conclusive negative correlation between RSS and content of NH$_4^+$ 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$_3^-$ 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

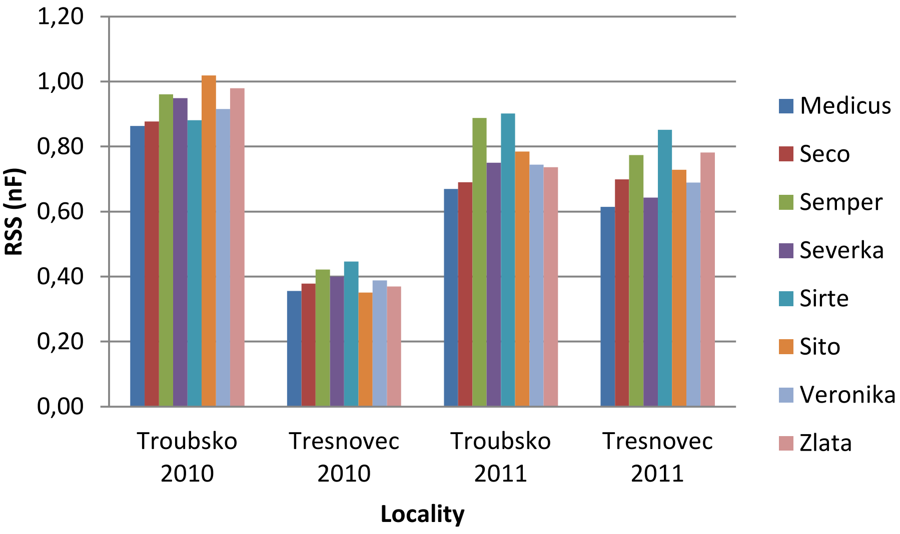

Figure 1: **Genotypic variability of Root system size (RSS) in dependence of location and year** (mean values from 3 measurements)

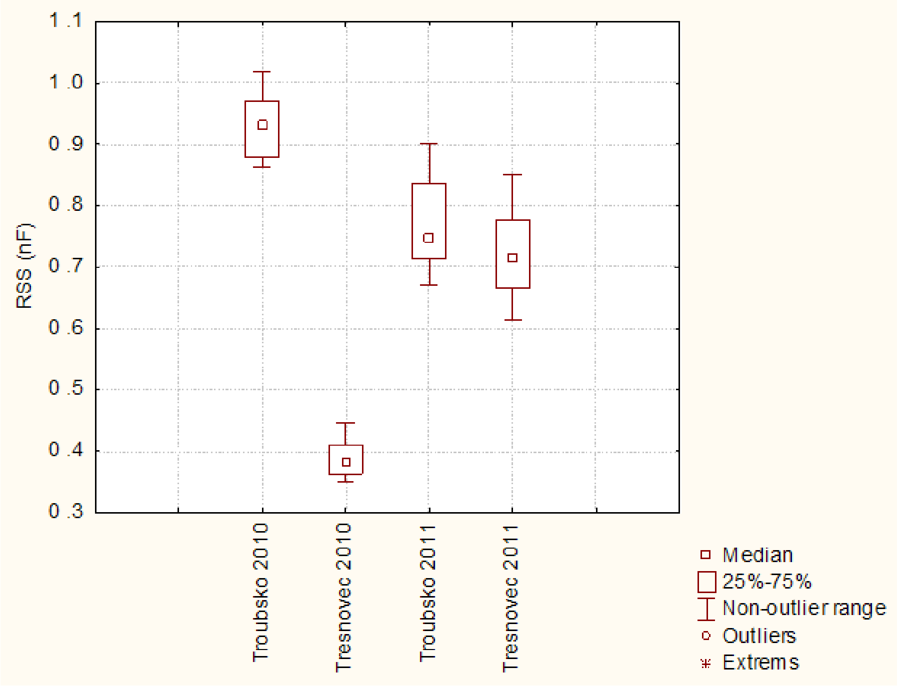

Figure 2: **Variability of root system size (RSS) according to environments** (means over all tested varieties)

Table 1: **Comparison of genotypic means of root system size (RSS) at different development stages and environments** (Means with the same letters are not significantly different)

Variety	Troubsko 2010		Tresnovec 2010		Troubsko 2011			Tresnovec 2011		
	STE[1]	FLO	STE	FLO	STE	FLO	RIP	STE	FLO	RIP
Medicus	1.24^{ab}	0.49^{a}	0.46^{bc}	0.25^{ab}	0.93^{b}	0.69^{ab}	0.40^{a}	0.78^{ac}	0.55^{b}	0.52^{a}
Seco	1.22^{a}	0.54^{ab}	0.46^{b}	0.30^{cd}	1.06^{ab}	0.61^{a}	0.41^{a}	0.82^{ac}	0.68^{a}	0.59^{a}
Semper	1.38^{bc}	0.54^{ab}	0.52^{ac}	0.33^{de}	1.10^{a}	0.87^{e}	0.70^{d}	0.88^{abc}	0.70^{a}	0.74^{b}
Severka	1.34^{ab}	0.56^{ab}	0.53^{a}	0.27^{bc}	1.14^{a}	0.72^{abc}	0.38^{a}	0.76^{c}	0.57^{b}	0.60^{a}
Sirte	1.21^{a}	0.56^{ab}	0.53^{a}	0.36^{e}	1.34^{c}	0.84^{cd}	0.53^{c}	0.96^{b}	0.84^{c}	0.75^{b}
Sito	1.48^{c}	0.55^{ab}	0.48^{abc}	0.22^{a}	1.15^{a}	0.71^{ab}	0.50^{bc}	0.95^{b}	0.69^{a}	0.54^{a}
Veronika	1.33^{ab}	0.50^{a}	0.49^{abc}	0.29^{cd}	1.18^{a}	0.63^{ab}	0.42^{ab}	0.89^{ab}	0.56^{b}	0.61^{ac}
Zlata	1.35^{abc}	0.61^{ab}	0.49^{abc}	0.25^{ab}	1.03^{ab}	0.73^{bc}	0.45^{abc}	0.89^{ab}	0.74^{a}	0.71^{bc}

[1] STE, stem elongation; FLO, flowering; RIP, ripening

SRL had higher RSS (higher electrical capacity) and lower NO_3^- nitrogen balance in the soil at the end of vegetation. Rather suprising 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 longterm 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.

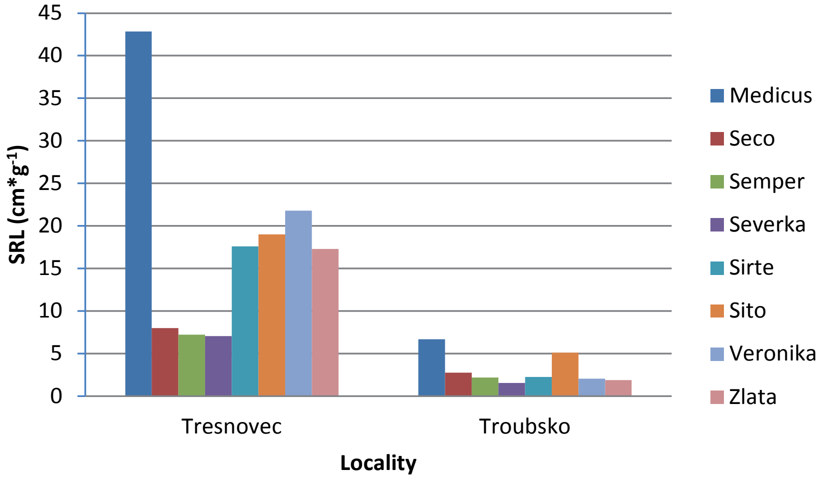

Figure 2: **Variability of root system size (RSS) according to environments** (means over all tested varieties)

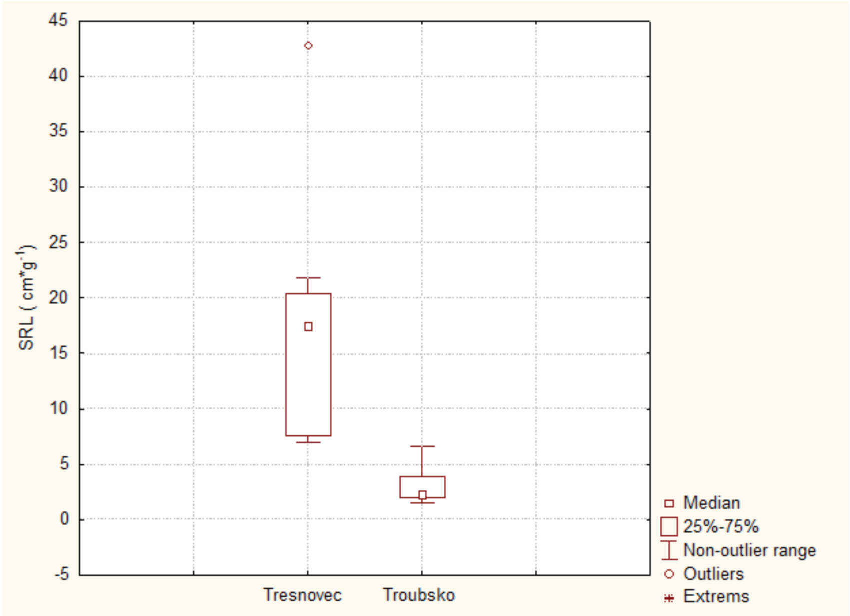

Figure 4: **Variability in specific root length (SRL) at the two test locations** (means over all varieties in 2010)

Acknowledgements

This research was supported by the Czech Ministry of Education, Youth and Sports, grant MEB061013.

References

BODNER G, KASTELLIZ A, LIEBHARD P, LOISKANDL W, HIMMELBAUER M, KAUL HP, 2011: Wurzeleigenschaften von Zwischenfrüchten und ihre agroökologische Funktion. 1. Tagung Öst Ges Wurzelforschung, 13-14 Sep, LFZ Raumberg-Gumpenstein, Irdning, 67-74.

CHLOUPEK O, 1977: Evaluation of size of a plant´s root system using its electrical capacitance. Plant Soil 48: 525-532.

CONSTANTINE J, BEAUDOIN N, LAURENT F, COHAN JP, DUYME F, MARY B, 2011: Cumulative effects of catch crops on nitrogen uptake, leaching and net mineralization. Plant Soil 341: 137-154.

FRANCIS GS, BARTLEY KM, TABLEY FJ, 1998: The effect of winter cover crop management on nitrate leaching losses and crop growth. J Agric Sci 131: 299-308.

HERRERA JM, LIEDGENS M, 2009: Leaching and utilization of nitrogen during a spring wheat catch crop succession. J Env Qual 38: 1410-1419.

KURPELOVÁ M, COUFAL L, ČULÍK J, 1975: Agroklimatické podmienky ČSSR, 1. vyd. Príroda, Bratislava.

MEISINGER JJ, HARGROVE WL, MIKKELSEN RL, WILLIAMS JR, BENSON VW, 1991: Effects of cover crops on groundwater quality. In: Hargrove WL (Ed.), Cover crops for clean water, Proc Int Conf, 9-11 Apr, Jackson, TN, pp. 57-68. Soil Water Cons Soc, Ankeny, IA.

SMUKALSKI M, ROGASIK J, OBENAUF S, 1991: Cultivation of cover crops to control nitrate leaching, In: Hargrove WL (Ed.), Cover crops for clean water, Proc Int Conf, 9-11 Apr, Jackson, pp. 82-84. Soil Water Cons Soc, Ankeny, IA.

STŘEDA T, DOSTÁL V, CHLOUPEK O, BODNER G, 2009: Šlechtění a výběr odrůd obilnin s větší tolerancí k suchu. Úroda 57(5): 10-12.

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 - Saatzüchtertagung - Saatzüchtertagung 2011) or requested from the corresponding author.*