THE COMPARISON OF ROOT SYSTEM SIZE AMONG SELECTED POPULATIONS WITHIN *MEDICAGO SATIVA* COMPLEX*

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The goal of this study was to compare the root system size among selected population within *Medicago sativa* complex. The experimental plants consisted of natural populations of *Medicago* species, collected in various regions of Slovakia, Czech Republic, Poland, Kazakhstan, and Ukraine. In spring 2006, forty plants from each population were transplanted to experimental field at a uniform space 40 x 40 cm in four replicates, ten plants in one replicate. In autumn 2008, the root size estimates based on electrical capacitance (RSS method) and root weight measurement in the layer 0–20 cm were realized by selected populations at five plants in two replicates. The results of measurement within *M. sativa* complex confirmed significantly lowest capacitance and total root weight in arable layer at *M. falcata*. *M. sativa* reached the highest capacitance but total root weight at layer 0–20 cm was significantly lower in comparison with *M. varia*. It is possible to conclude that *M. varia* populations produced higher amount of root biomass in the arable layer but had significantly lower root size than *M. sativa* in our experimental soil conditions.

forage; alfalfa; electrical capacitance of root system size

INTRODUCTION

Lucerne (*Medicago sativa* L.) is one of the most important forage species throughout the world. The genus *Medicago,* which comprises over 60 annual and perennial species, has basic genomic number $x = 8$, except for a few annual species which have $x = 7$. Diploid, tetraploid and hexaploid species occur in the genus. Taxonomically, species are distinguished mainly by pod and seed characteristics, pubescence, pollen grain morphology and chromosome number. The *M. sativa* complex includes taxa, which hybridize freely and are considered as *subspecies* on the basis of morphology and ploidy (Quiros, Bauchan, 1988). Its main 2 *subspecies*, *sativa* and *falcata* show very different morphological traits. The *ssp. sativa* has purple flowers, a tap-root, an erect growth habit, coiled pods and no winter dormancy. The *ssp. falcata* has yellow flowers, branched root system, prostrate growth habit, sickle-shape pods, strong winter hardiness and winter dormancy (Klesnil et al., 1965). These *subspecies* are often referred to as *Medicago sativa* L. and *Medicago falcata* L. Except these *subspecies*, *sativa* complex included *subspecies coerula* and *glutinosa* (Quiros, Bauchan, 1988). The most important hybrid within *M. sativa* complex is between *M. sativa* and M. *falcata*, referred as *Medicago varia* (Martyn) with various colour of flowers and at least 1.5 coil per pods (Kubát et al., 2002).

The evaluation of root size is very difficult mainly by *species* with tap-root reaching deeper than arable layer. Root system size (RSS) can be determined using electrical capacitance measured in relation to the surrounding soil with the dry surface of aboveground parts of the plants (Chloupek, 1972, 1977). The method is based on polarization of biological membranes in the root system. However, the measured values are "contaminated" by electric capacitance of the surrounding soil, wires etc., with the result that comparisons can only be made among plants of the same species measured in the same soil and under uniform moisture conditions. The "parasitic" capacitance much depends on the soil water, since water has a high dielectric value. A current must be lead to the whole root system. This may be a problem in older plants, which are sometimes disintegrated due to root rot (Chloupek et al., 1999) or if a large portion of the root was naturally damaged (Kendall et al., 1982). This method is used mainly for breeding selection of various cultural *species*, e.g. Chloupek et al. (1999) or Chloupek et al. (2003). According to Chloupek et al. (1999), progenies of lucerne plant with large RSS tended to have a large RSS and higher forage yield than progenies of plants with small RSS.

The described differences within *M. sativa* complex are concerned mainly on traits of aboveground part of plants (e.g. Pelikán et al., 2007). There are lacks of

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exact investigations in literature, which have compared the root biomass amount among two main subspecies and the most important hybrid form in the same experimental conditions. We now report the results of an experiment, which compared the root system size among selected populations within *Medicago sativa* complex.

MATERIAL AND METHOD

In 2006, the field experiment was established at the experimental station of PPRC – Research Institute of Plant Production in Piešťany (162 m above sea level, 48°35´N, 17°50´E). The long-term annual temperature is 9.2 °C and precipitation 595 mm. The soil at the experimental station site is Haplic Phaeozem, characterised as clay-loamy soil. The evaluation of the soil nutrients using the method Mehlich II have shown high magnesium and calcium reserves, medium phosphorus reserves and medium to low potassium reserves.

The experimental plants consisted of natural populations of *Medicago* species, collected in the frame of collecting expeditions carried out by researchers of PPRC in various regions of Slovakia, Czech Republic, Poland, Kazakhstan, and Ukraine. The population's abbreviations and origins are summarized in Table 1. In February 2006, seeds of evaluated populations were sown in a greenhouse. In May, forty seedlings from each population were randomly selected and transplanted to experimental field at a uniform space 40 x 40 cm. The experimental design was a randomised complete block in four replicates, ten plants in one replicate.

In autumn 2008, the root size estimates based on electrical capacitance (RSS method) and root weight (RW) measurement in the layer 0–20 cm were realized by selected populations at five plants in two replicates. With respect to destructive assessment of root weight, this research was realized in the very last year of experiment. For RSS measurement, LCR meter ELC-131D was used. The instrument was set on parallel measured capacitance in nF units on 1 kHz frequency. According to Chloupek et al. (1999), a frequency 1 kHz is suitable to evoke polarization on biological membranes. All stems of the measured plant were connected by tongs in the height of 2 cm above soil surface and second electrode was located 20 cm from measured plant (Fig. 1). The total dry matter root weight was assessed for each sample (five plants) and average root weight of one plant was calculated. One-way analysis of variance and regression analyses were performed using Statistica 6.1 (StatSoft, 2003).

RESULTS AND DISCUSSION

Differences among populations in agronomic traits were published by Drobná (2008). The means and standard errors of measured root parameters at evaluated populations are shown in Table 1. All the populations of *M. falcata* reached the significantly lower capacitance value (RSS) in comparison with *M. sativa* populations and *M. varia* POLKIE99-8. The observed total root weight of *M. falcata* populations was significantly lower than for all *M. varia* populations. *M. romanica* is not included within *Medicago sativa* complex and its results are reported as supplement, when the lowest values of measured parameters were obtained for population of *M. romanica* from Ukraine.

Table 2 shows differences among groups within *M. sativa* complex. According to Frame et al. (1997), *M. sativa* and *M. varia* types have a strong tap-root, usually reaching 2–4 m in depth, but root penetration can be deeper in well-drained, deep soils. In contrast, *M. falcata* types have thinner, more branched roots. In this experiment, the capacitance values represent size of all active root system measured by electrical capacitance, whilst weights of roots represent only the arable layer 0–20 cm. Gentile et al. (2003) detected root of three forage species including lucerne to a depth of 1 m and reported that half of the root

Table 1. Means of root system size expressed by its electrical capacitance (RSS, nF per plant) and root weight (RW, g dry matter per plant) among evaluated populations (SE = standard error, letters document statistical differences for Tukey HSD, α = 0.05)

Variety/population	*Subspecies*	Origin	RSS (nF per plant)		RW (g DM per plant)
			mean	SE	mean
Pálava	*M. sativa*	CZE	1.30 ^{A}	0.16	29.1 ^{AB}
Vanda	*M. sativa*	SVK	1.36 ^{A}	0.15	28.0 ^{AB}
CZEPOD00-18	*M. sativa*	CZE	1.28 ^{A}	0.13	27.2 ^{AB}
SVNPIR01-198	*M. sativa*	SVN	1.43 ^{A}	0.22	23.6 ^{AB}
POLKIE99-8	*M.varia*	POL	1.20 ^{A}	0.15	38.5 ^{A}
SVKNTAT01-320	*M. varia*	SVK	1.01 ^{AB}	0.11	31.0 ^{A}
SVKNTAT01-497	*M. varia*	SVK	0.86 ^{ABC}	0.15	31.8 ^{A}
SVNPIR01-83	*M. falcata*	SVN	0.31 ^{CD}	0.07	15.3 ^{BC}
SVKPOV96-40	*M. falcata*	SVK	0.39 ^{CD}	0.04	15.0 ^{BC}
SVKSIT971-10	*M. falcata*	SVK	0.44 ^{BCD}	0.04	11.2 ^{BC}
UKRKRY98-288	*M. romanica*	UKR	0.25 ^{D}	0.03	8.7 ^{BC}
			$N = 10$		$N = 2$

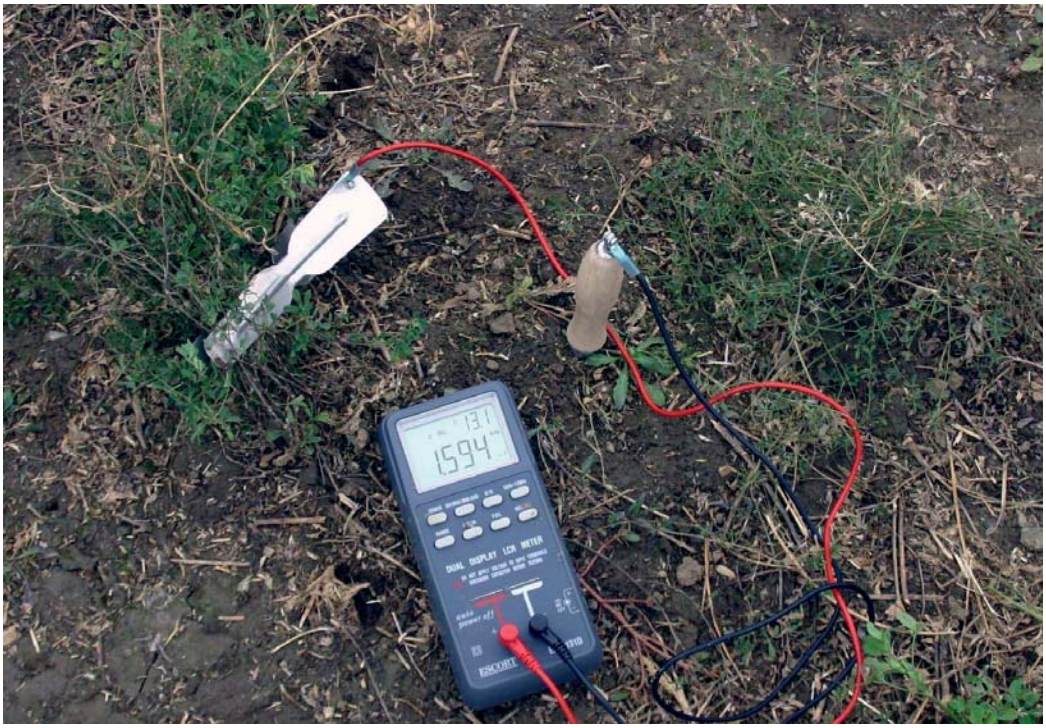

Fig. 1. Root system size measured as electrical capacitance by LCR meter ELC-131D

biomass for each species was located in the top 20 cm of the soil. This is in accordance with Klesnil et al. (1965), who state that approximately 30–50% of the root biomass is in the arable layer. Similarly, Hakl et al. (2009) described in preliminary results that over 50% of the lucerne root biomass in the arable layer was situated in the top layer 15 cm below the soil surface. The root biomass decreased quickly in subsequent layers and the layer 25–35 cm below the soil surface represents only 10–20% of the root biomass in the arable layer. As we expected, the significantly lowest capacitance value and total root weight were observed at *M. falcata*. *M. sativa* reached the highest capacitance value but total root weight at layer 0–20 cm was significantly lower in comparison with *M. varia*. Based on this result, it is possible to conclude that *M. varia* had lower root system size in comparison with *M. sativa* but achieved higher root amount in the arable layer. It is in accordance with Klesnil et al. (1965) who described more branched root system in arable layer at *M. varia* in comparison with *M. sativa*. This could be reason for better adaptability of *M. varia* types for worse conditions with shallow soils where these types are able to produce higher amount of roots. In our experimental conditions, *M. sativa* in well-drained, deep soil provided the largest root system size in spite of the fact that produces less root biomass in arable layer in comparison with *M.*

Table 2. Means of root system size expressed by its electrical capacitance (RSS, nF per plant) and root weight (RW, g DM per plant) among subspecies within *Medicado sativa* L. (SE = standard error, letters document statistical differences for Tukey HSD, α = 0.05)

	RSS per plant (nF)			RW per plant (g)		
	mean	SE	*N*	mean	SE	*N*
M. sativa	1.34 ^{A}	0.08	40	29.98 ^{A}	5.00	8
M. varia	1.03 ^{B}	0.08	30	33.76 ^{B}	10.67	6
M. falcata	0.38 ^{C}	0.03	30	13.82 ^{C}	7.27	6

Table 3. Variance comparison between and within groups for root system size (RSS, nF per plant) and root weight (RW, g dry matter per plant).

Parameter	Variance	Between *subspecies*	Between populations			
			all	within *sativa ssp.*	within *varia ssp.*	within *falcata ssp.*
RSS	between groups	16.13	16.93	0.14	0.59	0.08
	within groups	16.87	15.97	10.20	5.08	0.69
RW	between groups	31 050	34 128	845	1 728	505
	within groups	6 400	3 321	553	1 687	1 081

varia. In this regard, not only used population, but also age of stand, soil compaction and stand density influenced root system development in these dense seeded stands (H a k l et al., 2007).

The significant correlation between capacitance value and root weight across all subspecies was found ($R^2 = 0.53$; $P = 0.0169$) but it does not correspond with differences between *M. sativa* and *M. varia*. This result is only approximate due to lower extent of entry data set. According to K e n d a l l et al. (1982), lucerne root weight was significantly related to capacitance values at the beginning and at the end of the season during seeding year. In addition, we must remember that in our experiment the root weight did not represent a whole root system but just the roots in the layer 0–20 cm.

The variance comparison between and within groups for root system size and root weight is presented in Table 3. Based on these results, it is possible to conclude that inter-*subspecies* variance of RSS was similar as intra-*subspecies* with the same results between and within all populations. In contrast, there were considerable higher variances of RSS within populations than between populations within each *subspecies*. Between groups variance for root weight was higher or similar as within groups, except for populations within *M. falcata* ssp.

CONCLUSION

With limited data from one year, the results of measurement within *M. sativa* complex confirmed significantly smallest root size and total root weight in arable layer at *M. falcata*. In our experimental condition, *M. sativa* reached significantly the highest electrical capacitance but total root weight in arable layer was significantly lower in comparison with *M. varia*. It is possible to conclude that *M. varia* types produced the highest amount of root biomass in the arable layer but had significantly lower root size than *M. sativa* in experimental soil conditions.

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HAKL, J. – HREVUŠOVÁ, Z. – KRAJÍC, L. – DROBNÁ, J. (Česká zemědělská univerzita, Fakulta agrobiologie, potravinových a přírodních zdrojů, Praha, Česká republika):

Porovnání velikosti kořenového systému u vybraných populací v rámci skupiny *Medicago sativa.*

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Cílem práce bylo porovnat velikost kořenového systému mezi vybranými populacemi rodu *Medicago* v rámci skupiny *sativa*. Hodnocené populace představovaly přírodní sběry z různých oblastí Slovenska, České republiky, Polska a Ukrajiny. Pokus byl založen v roce 2006 vysázením rostlin ve znáhodněných blocích se sponem 40 x 40 cm ve čtyřech opakováních po deseti rostlinách pro každou populaci. Měření velikosti kořenového systému pomocí kapacitního měření (RSS) a odběry vzorků kořenů do hloubky 20 cm proběhly na podzim 2008 ve dvou opakováních po 5 rostlinách. Výsledky potvrdily průkazně nejmenší velikost kořenového systému i hmotnost kořenů v ornici u poddruhu vojtěšky srpovité. U poddruhu vojtěšky seté byla zjištěna průkazně nejvyšší velikost kořenového systému, ale hmotnost kořenů v ornici byla průkazně nižší než u hybridní vojtěšky prostřední. Na základě výsledků lze říci, že v našich pokusných podmínkách hybridní vojtěška prostřední dosahovala ve srovnání s poddruhem vojtěšky seté průkazně vyšší hmotnosti kořenů v ornici, ale průkazně menší velikosti kořenového systému.

píce; vojtěška; RSS; elektrická kapacita

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