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Assessment of root interactions between linseeds and legumes in mixtures

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Abstract

This study focused on root development in different mixture crops. The present research was performed in Poland, (50°07 N: 20°05 E). The assessment of root distribution and root mass of *Pisum sativum* (pea = P), *Vicia sativa* (vetch = V), *Linum usitatissimum* (linseed = L) in pure sown and in mixture; *Pisum sativum* with *Linum usitatissimum* (P(L) and L(P)), *Vicia sativa* with *Linum usitatissimum* (V(L) and L(V)) in a soil profile of 0,30 m depth, aimed at providing new insights into water capture capacity. Perennial crops exhibited different total root biomass, root distribution. Legumes accumulated considerably higher total root biomass, while linseed, being annual, produced clearly lower root biomass. Root dry matter showed diverse patterns of roots system along the soil profile due to different root densities of the crops.

Interspecific relation between linseed and vetch or linseed and pea in mixture depending on species component in mixture and weather conditions in years. Stronger relations between plants were noticed in mixture, regardless of weather conditions in years. Intraspecific relation among individuals plants of a single vetch and linseed species in pure sow were faint, regardless of vegetation years. Stronger relations among single linseed crop were noticed in 2006. Differentiation in root mass relations depending on water abundance in soil level. Drought, which was observed in flowering stage - July of 2006, resulted in stronger influence intraspecific relations between plats in sole crop. In 2007 drougth, which was earlier – in April, affected in weakness influence of intracpecific relations in pea sole crop.

This study shows that crop mixture may greatly differ in terms of water capture and root distribution, a fact that should be taken into great account in optimizing the land use change. According to these factors new mixtures may be classified with respect to the roots mass and term of water consumption. Information on benefits from appropriate plant mixtures regarding root mass and is provided by experimental results. Roots distribution was strictly related on weather conditions link with water content in soil. We can suspect, that different soil conditions and weather conditions, may shown different natural solution for this species.

Keywords: mixture crops, competition, root system

Introduction

Plant cooperation is most evident during a seedling phase, when neighbourhood of more seedlings causes easier overcoming the mechanical resistance of the surface soil layer (ZANNONE et al. 1986), while root competition is not so clear. MALCOLM (1966) believes that the plant competition is observed when the individual biomass production decreases in comparison to the sole crop production. EDDOWES (1969) states that two plants compete with each other when growth of one or both of them is weakened, or the habitus is modified in comparison to the growth or shape of plants that grow in sole crops. Similar or identical water and nutrients demand by all co-existing individuals causes strong competition which results in decrease of biomass of a single plant with increasing number of plants per area unit. On the other hand yield from the area unit increases with the density, but only to a certain limit, beyond which a it starts to decrease. The prediction that intraspecific competition must be more intense than interspecific competition is based on the idea that a greater similarity in requirements should occur between conspecific than heterospecific neighbours (MacARTHUR and LEVINS 1967). In general, many studies whose results relate to this prediction have been performed in ecosystems in which both aboveground and below-ground competition are important. KEDDY (1991) found that intraspecific competition was more intense than interspecific competition. By contrast, in arid and semiarid communities, intense below-ground competition is particularly important (FOWLER 1986). Differences in the dynamics of resources (i.e. soil and water resources) are at the core of understanding interactions among plants in both wet and dry soil conditions. Numerous studies describe interactions between root systems of plants both in sole crops and in mixtures (ATKINSON 1983, CALDWELL 1987).

The aim of this research was to establish inter- and intraspecific relations between roots of legumes; *Pisum sativum* and *Vicia sativa* and non-legumes –*Linum usitatissimum*, depending on type of sowing.

Material and methods

The experiment was conducted under field conditions at the Field Crop Research station of University of Agriculture in Prusy (50°07 N latitude, 20°05 E longitude, 300 m above mean sea level) in the period of 2006-2007. The experiment in Prusy was established in Umbrisol. Soil ensure good habitat for the analyzed plants. Umbrisol occurs pointwise and is considered the best for demanding crop plants.

During the conducted field experiment in Prusy acute drought was observed in July of 2006, in April of 2007.

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Drought occurred in Prusy in May. In the remaining months the weather conditions were optimal for growth and development of plants. It needs to be stressed, that soil conditions was more favorable for growth of the analyzed plants and their mixtures.

A split-plot in a randomized complete block design with four replications was used in the experiment. Three species in various methods of sowing were the plot treatment factors. Field pea (*Pisum sativum* L. cv. Ramrod), spring vetch (*Vicia sativa* L. cv. Ina) and flax (*Linum usitatissimum* L cv. Flanders) were grown in the sole crop and in mixtures with substitutive design in the following years of the experiment. The replacement design involved the replacement of a proportion of one species with another. A 0.5:0.5 replacement design was used: each species was sown at 50% of its sole crop population (*Table 2*). The size of each plot was 1.25m x 8 m. Weeds, pests and diseases were controlled with appropriate pesticides. Crops were fertilized with 30 kg×ha^{-1} N, 56 kg×ha^{-1} P and 139 kg×ha^{-1} K in 2006, 2007 in each soil type.

The roots were sampled using the soil-core method (BÖHM 1979) in summer, in the flowering stage. The core diameter was 80 mm. The samples were taken from a 30 cm depth and were divided into 2 sections: 0-15 and 15-30 cm. The roots were washed using a hydropneumatic elutriation system (SMUCKER et al. 1993) to remove mineral particles. Before scanning, all organic contaminations were manually removed. Digital images were obtained with an Epson Perfection 4870 Photo scanner. The collected images were saved in the .tiff format with a resolution of 600 dpi. After scanning, roots were dried at 70°C for dry matter determination (RDM).

Results

The performed analysis of variance suggests differences in root matter of the compared plant species (*Figure 1*). The root development in Umbrisol was significantly affected by the method of sowing. Pea cultivated in the mixture with linseed developed significantly ($p<0.05$) lower root matter, whereas the sole crop of pea was more favorable (*Figure 1*). Furthermore, differences in root matter were observed in various years of the experiment and significant correlation with ($p<0.01$) the method of sowing was detected. Root matter of pea was very high in 2006 in the sole crop, whereas the mixture of pea and flax in 2007 resulted in low root matter of pea. The lack of production advantages in 2007 was the result of drought in the sowing month.

Competition significantly reduced mass of both species during 2006 and 2007. Plants growing in pure sow (reduce inside crop competition effect) had higher root mass than plants growing with competition ($P<0,05$ both years; *Figure 1,2*). The lack of an effect of neighbour identity on the reduction of mass of targets plants is shown by the equal effects of intra and interspecific competition. Vetch and linseed root development was reduced by competition similar way during vegetations period (*Figure 2*).

Interspecific relation between two species in crop mixture depending on species component in mixture and weather conditions in years (*Figure 1*). Stronger relations between

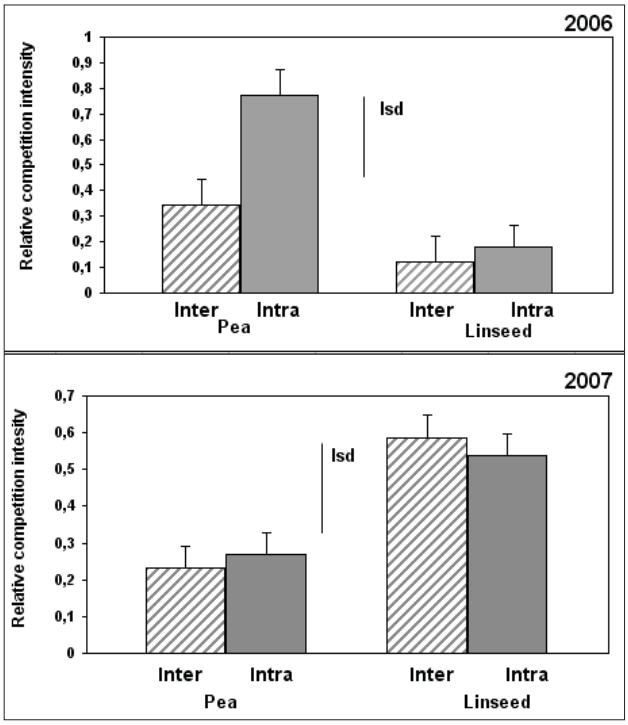

Figure 1: **Relative competition intensity for intraspecific (Intra) and interspecific (Inter) competition in *Pisum sativums* and *Linseeds*. Bars represent ± 1 SE. lsd bar was calculated with the experimental error for the year ($P < 0.05$).**

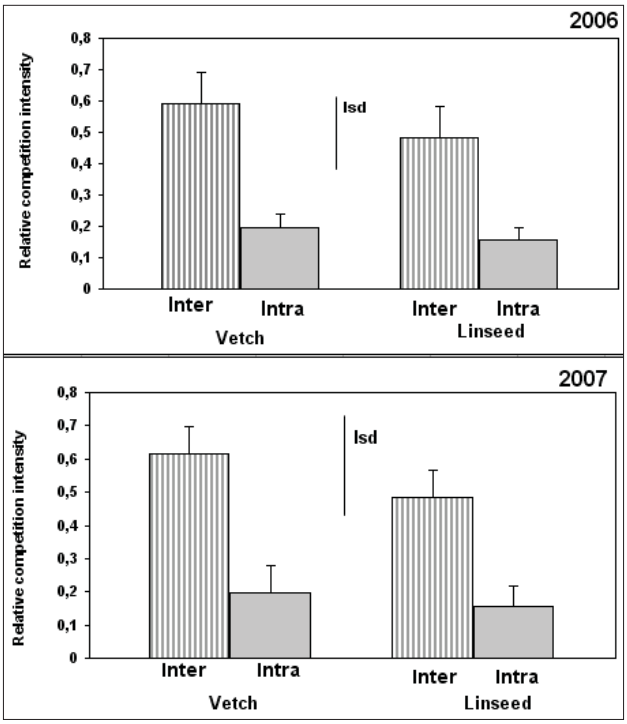

Figure 2: **Relative competition intensity for intraspecific (Intra) and interspecific (Inter) competition in *Vicia sativum* and *Linseeds*. Bars represent ± 1 SE. lsd bar was calculated with the experimental error for the year ($P < 0.05$).**

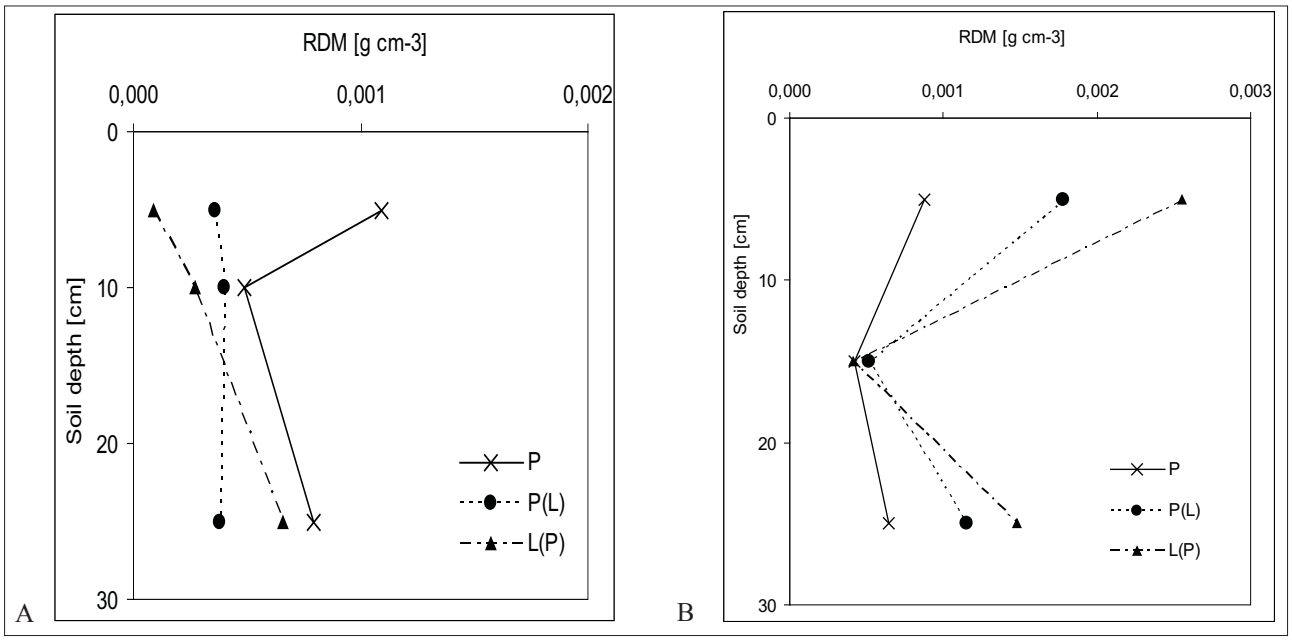

Figure 3: **Root dry matter (RDM) of pea development in pure sow (P) and in mixture with linseed (P(L)), during flowering stage in different years; 2006 and 2007**

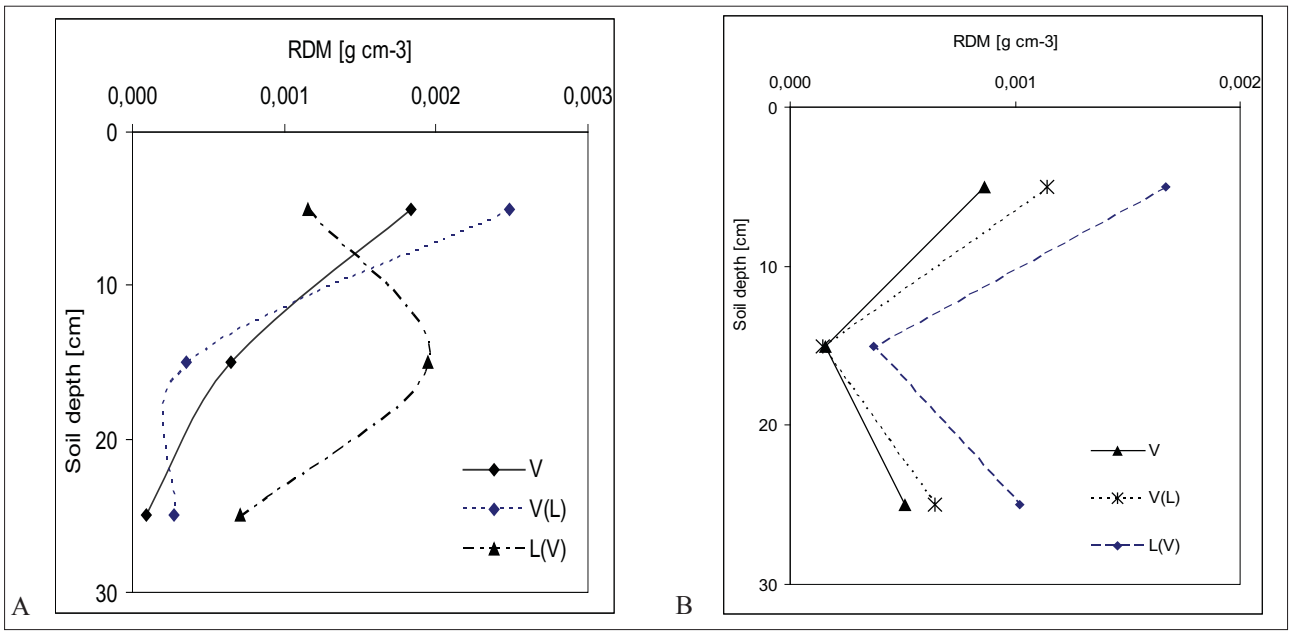

Figure 4: **Root dry matter (RDM) of vetch development in pure sow (V) and in mixture with linseed (V(L)), during flowering stage in different years A - 2006 and B- 2007**

pea and linseed were noticed in 2007, but linseed developed higher root system, because competed more effectively for water in soil. Intraspecific relation among individuals pea plants in sole crop were faint, regardless of vegetation years, albeit, weakness in 2007. Different situation were occured among individuals plants of a single linseed species in crop. Stronger relations into single linseed crop were noticed in 2006. Differentiation of root mass depended on water abundance in soil level. Drought, which was observed in flowering stage - July of 2006, resulted in stronger influence intraspecific relations between plats in sole crop. In 2007 drougth, which was earlier – in April, affected in weakness influence of intracpecific relations in pea sole crop.

Interspecific relation between linseed and vetch in mixture depending on species component in mixture and weather conditions in years (*Figure 2*). Stronger relations between plants were noticed in mixture, regardless of weather conditions in years. Linseed developed higher root mass each year, which was useful for water capture during vegetation period.

Intraspecific relation among individuals plants of a single vetch and linseed species in pure sow were faint, regardless

of vegetation years. Similar situation were noticed among individuals plants of a single species in crop. Weakness relations into single linseed and vetch were noticed in sole crop.

Roots distribution of pea very in years and depending on type of mixture and species (*Figure 3*). Water requirement of peas are low, bur really important during germination -April and flowering stage - June. In 2006 drought was observed in July, hence root distribution of pea and linseed in mixture was different and specific for each species. However, we noticed peculiar roots distribution of pea in the upper layer, what it may indicated moisture stress conditions during germination. In 2007, the rainfall was limited earlier, since April – during plant germination, and created wide range of root system distribution till 15cm depth of soil layer.

Vetch roots mass of distribution very in years and depending on type of mixture and species (*Figure 4*). In 2006 drought was observed in July, hence that root distribution in soil depth was different and specific for each species in mixture. In 2007, the rainfall was limited earlier, since April – during plant germination. This situation was strongly harsh for vetch roots system, which relocated roots mass in upper soil level.

Discussion

AGUIAR et al. (2001) were found that intra and interspecific competition had the same effect on the root growth rate. Our results have proved that specific relations between plants in below ground might be able to give a harsh pressure into above ground relation. In spite of the fact that our research was conducted in flowering stages, we can not be sure how root system developed in mixture from the beginning. The studies prove that physical properties of roots change when plants coexist. The performed analysis of variance showed that the root system of the analyzed plants was significantly affected by the method of sowing. Significantly ($p<0.05$) higher root matter of plants were obtained in sole crops, whereas lower variations of roots mass were obtained in mixtures. The relation of morphological characteristics of roots and soil conditions indicated the species diversity. ITOH et al. (2009) proved, that the root matter of plants depends on soil and water conditions, that change annually. The authors suggest, that compared to heavy soils, moderately rich soils provide better conditions for the development of root matter. The root matter is lower in heavy loamy soils, because plants must also overcome the soil resistance. TREDER et al. (2008), who presented different approach, suggested greater importance of plant competition for the habitat resources in the canopy. The presented research indicated that the soil type significantly affected root mass of legumes, while for the root mass of linseed this impact was smaller. In the presented study significantly higher root matter values were observed for pea and vetch ($p<0.001$) in Umbrisol and an increase of linseed root matter was observed. The development of root system is particularly important when drought occurs after sowing or during flowering phase (FAGERIA 2004). As a result of drought soil becomes hard which negatively affects the root system morphology and, as a consequence, affects the possibility of water and nutrients uptake (BENGOUGH et al. 2006). The greater the soil compaction the greater the resistance to roots (GŁĄB 2008). It is believed, that water and nutrient uptake is determined by root morphology and distribution of side branches (FAGERIA 2004). A significant variation in the root matter of pea, vetch and flax was observed in the presented research depending on the water conditions. Pea and flax cultivated in mixtures were more sensitive to drought, which occurred in April, i.e. after sowing and during the plant emergence. On the other hand, the legumes - vetch and pea - in sole crops were more sensitive to the lack of water during the flowering phase. These studies confirm the results obtained by PANDEY et al. (1984) or LIU (2009), indicating that the drought resistance may be improved by better species selection regarding the soil and climatic conditions in the sole crop and in mixtures.

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