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Effects of White Lupine on Phosphorus Use Efficiency of Soya Bean under Controlled Conditions

- Short Communication -

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Abstract: White lupine (*Lupinus albus* L.) is considered as highly efficient in the P uptake and utilization of sparingly available source of soil phosphorus, due to morphological and physiological adaptations of roots. These plants have short roots with high density of rootlets, which poses a mechanism of the increased biosynthesis and efflux of citrate, which are capable of solubilising complexed aluminium (Al) and iron (Fe) from Al- and Fe-phosphates by chelation, thus increasing the availability of P. The aim of this work was to show that soya bean (*Glycine hispida* Max) could use a part of P that was mobilised in the lupine rhizosphere under conditions of low availability of P. Plants were grown in a greenhouse, in pots with acid soil and low available P (pH 5,5; 39 mg kg^{-1} P). White lupine and soya bean were grown as a single crop, as a control, and intercropped as well. The concentration of P in the white lupine leaf (0.20 % P) was significantly higher compared to soya bean (0.14% P) when grown separately (control). Leaf P concentration of soya bean intercropped plants was significantly increased compared to the single crop soya bean plants (around 43%) and reached the concentration obtained for lupine grown as the single crop. The P concetration in intercropped soya bean roots was only slightly increased compared to the single crop, while the highest P concentration occurred in white lupine. Results indicate that intercropping in general, can increase P availability for P-inefficient plants, particularly in acid soils where P from fertilisers can be immobilised due to a high content of Al and Fe.

Key words: Cluster roots, efficiency, phosphorus, soya bean, white lupine.

Introduction

Cluster roots are considered, along with mycorrhizas and nitrogen-fixing nodules, to be one of the major adaptations to the nutrient acquisition. By now their formation was found in many plant families including *Fabaceae*, *Betulaceae*, *Myricaceae*, *Eleagnaceae*, *Casuarinaceae* and *Moraceae*, ***Skene***, 1998. White lupin (*Lupinus albus*) has been used as a model plant in many studies concerning the function of cluster roots. It is considered as highly efficient in the P uptake and utilisation of sparingly available source of soil phosphorus, ***Neumann et al***., 2000. Under conditions of P starvation white lupin excretes large amounts of citric and malic acid from lateral rootlets of cluster roots. Due to their high concentration level a significant desorption of phosphorus from sparingly soluble Ca-P, Al-P, Fe-P and from phosphorus adsorbing Fe/Al humic acid complexes was mediated, by mechanisms of ligand exchange, ***Gardner et al***., 1983.

Intercropping plays an important role in effective utilization of resources, ***Van der Meer***, 1989. The interspecific facilitation of the P uptake by intercropped species in agro-ecosystems has been reported for organic P sources in numerous studies. According to ***Horst*** and ***Waschkies,*** 1987, white lupine increased the P uptake of intercropped wheat via chelation of Ca^{2+} by citrate exuded from roots and release of P from Ca-P complexes and faba bean facilitated P uptake by maize in field conditions, ***Li et al.,*** 2002.

The aim of this work was to show that soya bean (*Glycine hispida* Max) can use a part of P which is mobilised in lupine rhizosphere under conditions of low availability of P.

Material and Methods

The experiment was conducted in a glasshouse with regulated light and the temperature, in Belgrade, Serbia, during May and June of 2005. Seeds were planted (six seeds per pot) directly in the 2-l pots. Air-dried, sieved soil (3 mm) had a pH (H_2O) 5.5 and 39 mg kg^{-1} available P_2O_5. Plants were thinned six days after emergence. White lupine (cv Amiga) and soya bean (cv Nena) were grown as the single crop (control), four plants per pot and intercropped as well, two plants of both species. There were four pots by a sowing treatment, each pot was one replication. Four weeks after germination, plants were harvested and roots were washed from the soil. Roots and shoots were dried at 70°C for 48 h, dry ashed at 550°C for 8 h and the concentration of P was determined colorimetrically by the molybdenum blue method, ***Gericke*** and ***Kurmie*****s**, 1952.

The results are average values of two independent experiments. The analysis of variance was performed and the significance of differences was made by calculating LSD at $P<0.05$ using CoSTAT software.

Results and Discussion

Soya bean and white lupine were grown either intercopped or as the single crop in pots filled with a low soil P. A few cluster roots were formed on lateral roots of white lupine. The effects of intecropping on the P uptake are shown in Table 1. The P concentration in the white lupine leaf (0.20% P) was significantly higher compared to soya bean (0.14% P) when grown separately (control). In addition, they showed that intercropping significantly increased the wheat shoot growth and the shoot P content (mg P shoot^{-1}) of the wheat, but did not affect either of these parameters for lupine. White lupine growing under low P conditions are known to exude large quantities of organic acid anions (mostly citrate) and protons from their roots and this has been shown to improve their P nutrition, ***Dinkelaker et al***., 1989, ***Gerke et al***., 1994, ***Hocking et al***., 1997, ***Keerthisinghe et al***., 1998. The leaf P concentration of soya bean intercropped plants was significantly increased (0.20%) compared to the single crop soya bean plants (0.14%) and reached the concentration obtained for lupine grown as single crop. The improved P uptake of the soya bean inetrcropped with white lupine may be due to lupine exuding citrate and protons from their roots, mobilising P in excess of their own needs and then making the excess P available to their companion soya bean plants.

The P concentration in intercropped soya bean roots (0.21%) was only slightly increased compared to the single crop (0.19%), while the highest P concentration occurred in white lupine (0.3%) (Table 1). This is supported by findings of ***Watt*** and ***Evans***, 1999, showing that soya bean and white lupine acquired similar P per a unit root dry weight when grown in the low soil P. In their study, however, white lupine accumulated 4.8 times more P per a unit root length, suggesting that the P acquisition in these plants involved other mechanisms such as the exudation of P solubilising compounds.

Table 1. The P Concentration in Roots and Leaves of Soya Bean and White Lupine grown as the Single Crop (Control) and Intercropped in Pots Filled with Soil Deficient in Available P. Each Value is the Mean of Four Replicates

Koncentracija P u nadzemnoj masi soje i lupine, gajenih pojedinačno (kontrola) u združenoj setvi, u sudovima sa zemljištem deficitarnim u pristupačnom fosforu. Vrednosti predstavljaju srednju vrednost četiri ponavljanja

Sowing methods Način setve	Concentration of P - (%) - Koncentracija P	
	Roots - Koren	Leaves - List
Soya bean (single crop) Soja (čisti usev)	0.19	0.14
Soya bean intercropped with white lupine Soja u zruženoj setvi sa belom lupom	0.21	0.19
White lupine (single crop) Bela lupine (čisti usev)	0.30	0.20
$LSD_{0.01}$	0.13	0.05

Conclusions

Results indicate that intercropping of P-efficient plants such as white lupine in general can increase the P availability for P-inefficient plants, particularly in acid soils where P from fertilisers can be immobilised due to a high content of Al and Fe.

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Uticaj bele lupine na poboljšanje iskorišćavanja fosfora kod soje u kontrolisanim uslovima

- Prethodno saopštenje -

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I z v o d

Bela lupina (*Lupinus albus* L.) pripada grupi biljaka efikasnih u iskorišćavanju fosfora (P) iz kiselih zemljišta, zahvaljujući morfološkoj i fiziološkoj prilagođenosti korenovog sistema. Ove biljke formiraju guste bočne korenove male dužine (klaster korenovi) koji ispoljavaju adaptivni mehnizam povećane biosinteze i efluksa citrata. Citrati, kao jaki helatori, u rizosferi heliraju aluminijum (Al) i gvožđe (Fe) iz nepristupačnih Al- i Fe-fosfata, prevodeći ih tako u oblik pristupačan za biljke. Cilj ovg rada bio je stoga da se pokaže da soja (*Glycine hispida* Max), gajena u združenoj setvi sa lupinom u uslovima slabe obezbeđenosti zemljišta pristupačnim P, može da iskoristi deo P koji je u zoni korenovog sistema lupine preveden u pristupačni oblik. Biljke su gajene u staklari u sudovima sa kiselim zemljištem, deficitarnim pristupačnim P (pH (u H_2O) = 5,5; 39 mg P kg^{-1} zemljišta). Kao kontrola lupina i soja su gajene odvojeno kao čist usev. Koncentracija P u listu lupine (0,20 % P), bila je statistički značajno veća u odnosu na soju (0,14% P) kada su gajene kao čist usev (kontrola). U združenoj setvi koncentracija P u nadzemnom delu lupine nije se menjala u odnosu na kontrolu, dok se kod soje statistički značajno povećala (oko 43 % povećanja u odnosu na kontrolu). Ovi rezultati ukazuju da ovakav način združene setve može da utiče na poboljšano iskorišćavanje P kod P-neefikasnih biljaka, kao što je soja, posebno u jako kiselim zemljištima u kojima zbog visoke koncentracije Al i Fe postoji opasnost od imobilizacije P iz đubriva.

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