PHOSPHORUS DISTRIBUTION IN TWO SOYBEAN CULTIVARS AND CONTENTS OF PHOSPHATES IN SOIL IN RELATION TO PHOSPHORUS AND RHIZOBACTERIA APPLICATION UNDER TEMPORARY DROUGHT

DISTRIBUȚIA FOSFORULUI ÎN PLANTELE A DOUĂ CULTIVARE DE SOIA (*GLYCINE MAX*. L.,) ŞI A CONȚINUTULUI FOSFAȚILOR MOBILI ÎN SOL LA FERTILIZAREA CU FOSFOR ŞI BACTERII RIZOSFERICE ÎN CONDIȚII DE SECETĂ TEMPORARĂ

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Abstract. *The effect of phosphorus (P) deficiency on phosphorus uptake and distribution in legumes has been widely studied under normal water conditions. However, the response of P content in roots stems and leaves of Glycine max., to low P supply is not yet fully understood in relation to water regime of soil. In this study, two cultivars of soybean were grown in low and sufficient (100 mg P kg^{-1}) P supply with or without of rhizobacteria application. Results show that low P decreased growth, P contents in both cultivars Zodiac and Horboveanca as well as contents of available of phosphates in soil. Under low P supply the P concentration in soybean leaves increased more pronounced in Horboveanca, than in Zodiac. Fertilization with P alone or in combination with microorganisms significantly improved the contents of available phosphates in soil irrespective of water soil regime. Thus, application of P in particular with suspension of* pseudomonas fluorescence *and* azotobacter chroococcum *improved mineral nutrition of plants in both soil moisture regimes due to increase the availability of phosphates in soil.*

Key words: *phosphorus, rhizobacteria, drought, phosphates, soybean*

Rezumat. *Influența deficitului de fosfor (P) asupra absorbției şi distribuirii fosforului la leguminoase s-a studiat în condiții optimale de umiditate. Paternul distribuției conținutului de P în rădăcini, tulpini, frunze la Glycine max. L. în cazul insuficienței de P cu aplicarea microorganismelor rizosferice nu este elucidată pe deplin în dependență de regimul hidric al solului. Două soiuri de soia au fost crescute la nivel scăzut şi suficient de P pe solul de tip cernoziom carbonatic. Rezultatele cercetării au arătat că deficitul de fosfor a micşorat creşterea, concentrația P în rădăcini şi frunze la ambele cultivare ceea ce s-a asociat cu diminuarea conținutului fosfaților mobili în sol. S-a demonstrat că Horboveanca posedă o capacitate mai bună de alocare a fosforului în frunze mai ales în condiții deficitare de fosfor. Aplicarea fosforului separat sau în combinare cu bacteriile Pseudomonus fluorescence şi Azotobacter chroococcum a îmbunătățit nutriția cu fosfor a plantelor pe ambele fonduri de umiditate ale solului prin sporirea accesibilității fosfaților din sol.*

Cuvinte cheie: *fosfor, rizobacterii, secetă, fosfați mobili, soia*

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INTRODUCTION

Phosphorus plays a key role in plant growth and metabolism, participating in photosynthesis, respiration, biosynthesis of carbohydrates, lipids, phospholipids, enzyme activation/inactivation (Raghothama, 1999). The low solubility and higher sorption capacity of phosphates in soils make it relatively unavailable to plant roots. Therefore, in such conditions phosphorus deficiency is one of the major growth-limiting factors for plants in many natural and agricultural ecosystems. Hence, it is a key constraint to accomplish the potential crops productivity (Vance et al., 2003). Legumes, in comparison to cereals, have a higher phosphorus requirement for growth, nodulation and nitrogen fixation and that's why they are more susceptible to poor phosphorus nutrition. These species contribute not only to solving the problem of protein deficiency but also have an important ecological role, improving soil fertility and reducing the dose of chemical fertilizers. The positive effect of phosphorus due to mineral fertilization or due to application of rhizosthere microorganisms (Bethenfalway et al., 1988, Gyaneshwar et al., 2002) on plant growth and phosphorus uptake has been demonstrated in a number of researches as a rule under optimal humidity (Vadez et al., 1999). The application of rhizosthere bacteria could serve as reliable alternatives to properly replace the incessant application of chemical fertilizers in order to increase crop productivity (Adesemoye et al., 2009). It was established that rhizosthere microorganisms stimulate the absorption of nutrients, particularly of low mobility such as phosphorus (Glick, 1995, Dey et al., 2004). It is known that pattern of uptake, distribution and remobilization of phosphorus within plants is affected by environmental factors (Bieleski, 1973). The mobility of phosphorus in the soil, as well as its distribution in the plant parts depends to some extent on the environmental abiotic factors, particularly the soil moisture regime. Nowadays, the phenomenon of drought is commonly spread in many agricultural regions as well as in the Republic of Moldova and Romania. Droughts negatively affect the physiological processes including mineral nutrition of plants by reducing the availability of nutrients in the soil. Phosphorus deficiency and drought are therefore a major factors contributing to poor nutrition and yield of legumes. Although these abiotic factors exist simultaneously under field conditions however their impact on agricultural crops has been mostly studied independently.

The objectives of this study were to investigate the effect of inorganic P and rhizosthere bacteria *Pseudomonas fluorescence* and *Azotobacter chroococcum* applied to two soybean cultivars on P distribution and phosphates contents in soil under temporary drought conditions.

MATERIAL AND METHOD

To accomplish the objectives of this study it was conducted out a pot experiment in a green house under controlled humidity conditions. The research included two soybean (*Glycine max*., L.) cultivars Zodiac and Horboveanca that differ by potential productivity and responsiveness to phosphorus fertilization. The soil was cernoziom carbonated with low level of phosphorus, basic pH (7,7), which was mixed with sand in a 2:1 ratio (by volume). Seed inoculation with bacterial preparation was carried out on the basis of rhizobium japonicum. Phosphorus dose of 100 mg kg-1 was administered to the soil (P100) being regarded as sufficiently supplied with phosphorus and control treatment (P0) - deficient in phosphorus. The suspension of azotobacter chroococcum and pseudomonas fluorescens was applied to the soil before sowing. Soil moisture regime was achieved by watering to 70% of the water holding capacity of the soil (WHC) in the control as optimal value and 35% in WHC treatment option, being considered as water stress for soybean. Temporary drought regime began in the flowering stage and lasted 12 days. The plants were harvested at the end of water stress and separated into roots, leaves, stems, nodules. The total phosphorus content in plant tissues was determined by the method of Murthy and Riley (1962). The content of mobile phosphates in the soil was carried out according to Machigin (Mineev, 1989). Data in tables and figures represent the average value of the results of chemical analyze of plant and soil of three replications. The experimental results were analyzed statistically, determining significant differences at the level of P = 0.05.

RESULTS AND DISCUSSION

The conditions of nutrition and soil moisture had obvious repercussions on the pattern of total phosphorus content in leaves, stems and roots in both cultivars. The data of phosphorus concentration in cultivars Horboveanca and Zodiac are shown in Table 1 and 2. It was found that leaf phosphorus concentration showed lower values in particular for Horboveanca under phosphorus deficiency (control variant). The same trend was also observed in the roots. Phosphorus concentration in plant tissues increased in treatment with fertilization in both water regimes. Compared to the unfertilized control, total phosphorus content in leaves and roots of Zodiac increases by 18% and 34% in the variant by applying a sufficient dose of phosphorus (P100), under optimal conditions of humidity (70% WHC).

Table 1

Concentration of phosphorus (mg P/g) in leaves and roots of Zodiac and changes of ration between their concentration (Pl/Pr) in relation to phosphorus supply and rhizobacteria application (RH)

Variant	Leaves	Roots	Pl/Pr	Leaves	Roots	Pl/Pr
	70% WHC			35% WHC		
P0	1,85±0,07	3,52±0,07	0,52	2,12±0,02	3,22±0,16	0,66
P20	2,18±0,06	4,80±0,02	0,60	2,58±0,01	4,16±0,04	0,62
P100	2,50±0,03	4,81±0,04	0,52	3,22±0,09	4,96±0,18	0,65
P0 +RH	1,91±0,02	3,46±0,11	0,55	2,06±0,05	3,14±0,09	0,66
P100 +RH	2,22±0,07	4,83±0,01	0,46	3,30±0,05	5,10±0,08	0,65

These increases in leaves and roots of Horboveanca were 11% and 35,3% respectively. The analysis of experimental results revealed that the differences between cultivars were higher in the case of leaves. The same trend was observed in plants subjected to water deficit but the difference was more pronounced. Under water stress conditions the roots of Zodiac showed a greater potential for accumulation of phosphorus than Horboveanca. Reductions in uptake of nutrient were more evident in treatment with both abiotic factors: moisture deficiency and insufficiency of phosphorus. Under suboptimal moisture regime there was a better allocation of phosphorus in the leaves of Horboveanca, significantly exceeding the concentration recorded in Zodiac (*table 1 and 2*).

Table 2

Concentration of phosphorus (mg P/g) in leaves and roots of Horboveanca and changes of ration between their concentration (Pl/Pr) in relation to phosphorus supply and rhizobacteria application (RH)

Variant	Leaves	Roots	Pl/Pr	Leaves	Roots	Pl/Pr
	70% WHC			35% WHC		
P0	2,35±0,06	3,71±0,07	0,63	3,41±0,15	3,58±0,02	0,95
P20	2,63±0,17	4,05±0,03	0,65	3,14±0,22	4,22±0,19	0,74
P100	2,70±0,14	5,01±0,02	0,54	3,75±0,05	5,16±0,13	0,73
P0+RH	2,31±0,05	2,93±0,05	0,79	3,41±0,08	3,19±0,05	1,07
P100+RH	3,23±0,14	5,53±0,08	0,58	4,12±0,23	4,89±0,08	0,84

The application of bacterial suspension in the soil with low phosphorus fertility did not contribute to significant changes in the pattern of distribution of phosphorus within the plant's vegetative parts. However, the utilization of biofertilizers together with phosphorus increased significantly the total phosphorus concentration in leaves and roots of Horboveanca but their effects in Zodiac were less pronounced regardless soil moisture regimes. The phosphorus concentration in the stems of Zodiac cultivar had higher values after the administration of microorganisms (data not shown).

According to the data of the plants subjected to drought we could conclude that the leaves of Horboveanca had a better ability to accumulate phosphorus in treatment of combined application of phosphorus and microorganisms. The assessment of changing the ratio of the concentration of phosphorus in leaves and roots suggest about the ability of plants to transport phosphorus from roots to shoots. This index showed higher values in Horboveanca, especially in adverse humidity conditions. Managing rhizosthere bacteria scored poorly this report for Zodiac and the Horboveanca tended to increase the ratio to the reference variant (tab. 2). Improving phosphorus status in leaves leads to increase or at least to maintain the physiological activity at a higher level, with beneficial impacts on the whole plant productivity (Rao and Terry, 1989).

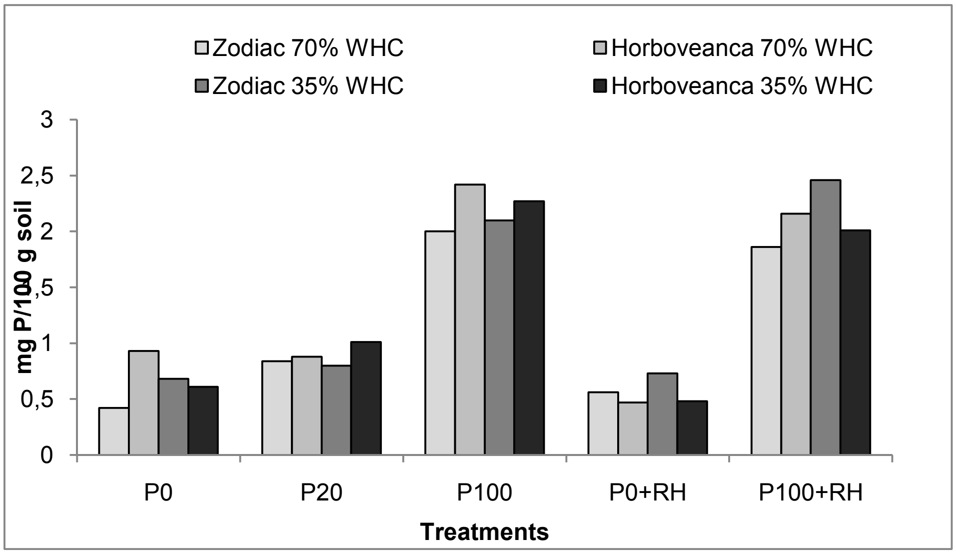

Fig. 1 - Influence of phosphorus and rhizobacteria (RH) on contents of phosphates in soil

Changes of the phosphorus contents in organs vary in relation to the availability of the nutrient phosphate in soil. It is important to know the changes that occur in the plant-soil system and that is useful primarily for resource efficiency strategies for soil and fertilizer in agriculture productivity. Considering that between the phosphorus content in plants and its availability in the soil is a strong correlation we examined the impact of the fertilization and application of microorganisms on the changes of phosphates in the soil (*fig. 1*). Supplementary nutrition increased phosphorus content in both varieties of mobile phosphates in comparison to the control. Thus, due to fertilization, the phosphorus content increased from 0,4 to 4,8 mg/100g soil in variant - P100. The lowest values of available phosphates were recorded for the control, regardless of the soil moisture level. Under the normal water regime the administration of biofertilizers to the soil vulnerable in phosphorus, in available forms, contributed to the increase of phosphate content only in pots cultivated with Zodiac. The same trend was observed in the case of rhizosthere bacteria application under water stress conditions. The administration of rhizosthere microorganisms without industrial fertilizer had no effect on the soil for available phosphate contents in pots where Horboveanca was cultivated irrespective of the soil moisture. The difference between cultivars in regards to the content of the phosphates in the soil probably could be explained through the chemical processes induced by the root system. Similar changes in rhizosthere have been mention by Hinsinger (2001). Soybean, unlike other species does not have the ability to form cluster roots, therefore it has other adaptation mechanisms to low phosphorus.

Hence, a clear improvement of soil fertility with phosphorus was established in variants with the use of mineral fertilizers alone or in combination with rhizosthere bacteria. The results obtained in the current study evidenced the improvement of P nutrition promoted the adaptation of plants to water deficits.

CONCLUSIONS

1. The application of phosphorus and suspension of rhizosthere microorganism's pseudomonas fluorescence and azotobacter chroococcum improved the phosphorus nutrition of plants irrespective of soil moisture.

2. Under phosphorus deficient conditions, cultivar Horboveanca has a better capacity for translocation of phosphorus in leaves and stems than Zodiac, particularly under temporary drought.

3. Fertilization alone or in combination with rhizobacteria increased the fertility of the soil through increasing the availability of phosphates in soil.

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