PLANT NUTRITION AND BIOMASS PRODUCTION OF SOYBEAN PLANTS UNDER UNFAVORABLE MOISTURE CONDITIONS

NUTRIȚIA MINERALĂ ȘI PRODUCEREA BIOMASEI LA PLANTELE DE SOIA ÎN CONDIȚII NEFAVORABILE DE UMIDITATE

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Abstract. *The interactive effect of phosphorus (P) and iron (Fe) on the growth of soybean (Glycine max.L Merr) plants under drought conditions was studied in pot experiments. In the experiments it was used soil cernoziom carbonated with deficiency in availability forms of P and Fe. Two levels of P and Fe supply were investigated. Control pots were kept at 70% of field capacity (FC) and water stressed pot were maintained at 35% FC during 14 days after initiation of flowering stage. P soil deficiency as well as temporal drought conditions significantly reduced plants growth. Adequate P nutrition increased biomass accumulati0n and nutrient uptake in water stress environment. Supplemental Fe nutrition also stimulated the plant growth but its effect was less pronounced. Responses of plant biomass production and P use efficiency were relative greater in treatments with both nutrients application. The experimental results confirmed that adequate mineral nutrition of plants could attenuate the negative impact of drought on crop production.*

Key words: biomass accumulation, nutrients, soybean, water stress

Rezumat. *În experiențele vegetative s-a studiat interacțiunea fosforului (P) şi fierului (Fe) asupra nutriției minerale şi creşterii plantelor de soia (Glycine max. L., Merr) în condiții de secetă. Plantele de soia au fost crescute pe solul de cernoziom carbonatic care s-a caracterizat printr-un conținut inferior de forme accesibile pentru plante de P şi Fe. S-a studiat influența a două niveluri de nutriție cu fosfor şi fier. Productivitatea maximă a plantelor s-a constatat în varianta control, unde umiditatea solului a constituit 70% din capacitatea de câmp pentru apă. La plantele supuse secetei în faza înfloritului (perioada a fost de 14 zile) s-au înregistrat indici mai inferiori în absorbția elementelor nutritive şi creştere. Nutriția adecvată cu P în condiții de stres hidric a intensificat procesul de acumulare a masei organice şi achiziționare a fosforului şi azotului. Nutriția suplementară cu Fe a avut un impact mai puțin pronunțat decât aplicarea P. Reacțiile producerii biomasei şi eficacitatea de utilizare a P au fost mai evidente în cazul aplicării concomitente a ambelor nutrienți. Rezultatele experimentale au dovedit că efectuarea nutriției minerale adecvate contribuie la atenuarea impactului negativ al secetei asupra plantelor de cultură.*

Cuvinte cheie: acumulare biomasă, nutrienți, soia, stres hidric.

INTRODUCTION

Plant productivity depends on a wide range of environmental factors. It was established that adequate mineral nutrition of crops with macronutrients and micronutrients plays a major role in sustainable plant metabolism. Hence nutritional imbalance could affect the tolerance of plants to environmental stresses. Many experiments have been shown that legumes respond significantly to phosphorus application (Al-Karaki G. et al 1996, Andreeva T.F., et al 1970). Its effect has a particular importance on soil with low available forms of phosphorus. Studies performed by Andries (2006) revealed that soils of republic of Moldova are characterized by low level of mobile forms of this nutrient. Phosphorus deficiency is more pronounced on carbonate cernoziom soils. In such type of soils the available forms is estimated around 0.5% of total phosphorus. However, the application of P fertilizers affects the pattern of absorption of others nutrients, in particular iron (Fe). Iron is involved in many physiological processes, such as electron transport in photosynthesis, it is a component of chlorophyll, Fe participate in CO_2 fixation, activates the function of nitrogenase enzyme (Tang C.X., et al 1992). Sufficient supply with Fe stimulates a wide range of physiological processes that in turn lead to produce yields of crops. In some investigations it was established that the supply of P is critical under moisture stress conditions. Also some experiments have been shown that application of phosphorus increased drought tolerance of cotton and white clover (Radin J.M., and M.P. Evidenbock, 1984, Singh D.K., and P.W.G. Sale, 2000). However, it is should be mentioned that such investigations were performed as a rule under normal water regime. There is a lack of information regarding the influence of both nutrients P and Fe on crop development under water stress.

The purpose of this study was to examine the effect of combined application of P and Fe on plant growth and nutrient absorption of soybean plants under water stress conditions.

MATERIAL AND METHOD

To accomplish the purpose of the study an experiment was laid out with two varieties of soybean, namely Zodiac and Licurici, in greenhouse conditions. There were used pots with 5 L capacity.

The soil was cernoziom carbonate which had low available forms of phosphates.

The effect of P and Fe interaction was examined in two water regimes: 70% water holding capacity (WHC), considered as optimal and 35% WHC - as water stress. Nitrogen (N) fertilizer was applied to all pots at rate 50 mg kg^{-1} soil, P at 100 mg kg^{-1} soil as KH_2PO_4. A concentration of 5 mg Fe kg^{-1} soil as FeEDTA was used to study its interaction with phosphorus.

Each treatment had 8 replications. Drought stress was imposed at the beginning of flowering and lasted 14 days. Soybean plants were harvested at the end of drought period. Vegetative plant parts were analyzed for N and P concentrations. Phosphorus was determined by the method of Murthy and Raley (Mineev V.G., 1989).

RESULTS AND DISCUSSIONS

The examination of experimental results revealed that biomass accumulation at the end of water stress period decreased substantially by the insufficiency nutrient supply as well as by water deficit. It should be noted that low P supply affected more evidently the plant productivity than shortage of moisture.

The maximum plant production was obtained in treatment with adequate P nutrition under normal moisture of soil where biomass in Licurici was 8.1 g/plant. Results of present study demonstrated that P fertilization of Licurici increased biomass production by 42.3% in normal water conditions and by 44.3% under drought conditions. Similar trend was denoted in soybean plants of Zodiac. It was observed a genotypic difference in biomass accumulation in relation to soil moisture levels. As regard the influence of iron the experimental data noted that it was observed a positive effect of micronutrient application on soybean plants, but the extent of biomass increase was lower than in treatments with P. Iron supplemental nutrition had a more significant effect under water stress conditions (table 1).

Abiotic factors changed the ratio between roots and shoots. The highest value of this parameter was observed in Zodiac. The combined application of both nutrients favorable affected the rate of P use efficiency. The process of nodulation was more sensitive to water stress and P deficiency than other vegetative organs. The symbiotic process responded positively in both cultivars to supplemental nutrient nutrition. In addition, the plant performance increased due to adequate nutrition irrespective of water regime. Similar effects have been established in other species (Tang C.X. et al. 1992, Al-Karaki, G.N. et al. 1996). Analyses of rates of P absorption demonstrated a positive correlation between P acquisition and plant productivity. Experimental results confirmed that nutrient application as well as soil moisture level implied the pattern of nutrient absorption (fig. 1).

There was established a genotypic difference in absorption of N and P under low soil fertility. This result is related of root development and their physiological activity. It is necessary to emphases that sufficient P supply increased N content in soybean leaves and nodules by 38% and 16% respectively. Supply of iron also stimulated N accumulation in leaves and stems, but had a little impact on roots and nodules. The maximum N concentration was denoted in treatment NPFe its value was 3.60%, while in control variant nitrogen level decreased to 2.87%. Drought reduced P accumulation and its negative effect was evident in treatment without fertilizer application.

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Table 1

The influence of phosphorus and iron on biomass accumulation of soybean plants in relation to soil moisture, g DW/plant

Treatments	70% WHC					35% WHC				
	leaves	stems	roots	nodules	plant	leaves	stems	roots	nodules	plant
LICURICI										
$N_{0.05}$ g/kg sol		1,38	0,81	0,04	3,88	1,06	1,26	0,59	0,02	2,93
$N_{0.05}$ $P_{0,1}$	2,74	2,62	1,20	0,16	6,72	1,70	2,49	0,93	0,14	5,26
$N_{0.05}$Fe	1,86	1,62	0,81	0,04	4,33	1,53	1,62	0,55	0,03	3,73
$N_{0.05}$ $P_{0,1}$ Fe	3,21	3,35	1,26	0,28	8,10	2,70	2,73	0,85	0,15	6,43
ZODIAC										
$N_{0.05}$ g/kg sol	2,00	1,72	0,95	0,05	4,72	1,24	1,35	0,67	0,02	3,26
$N_{0.05}$ $P_{0,1}$	2,84	2,74	1,15	0,22	6,95	1,76	2,34	1,02	0,10	5,22
$N_{0.05}$ Fe	1,90	2,10	0,74	0,05	4,75	1,35	1,78	0,66	0,03	3,82
$N_{0.05}$ $P_{0,1}$ Fe	2,95	2,80	1,02	0,41	7,18	2,45	2,55	0,95	0,20	6,15

Probably, low growth rate of leaves decreased plant demand in P and this nutrient is involved in expression of fed-back mechanism of regulation.

Evaluation of the effects of P supply shown that P application in sufficient dose facilitated P accumulation more significantly than N accumulation. Perhaps, nitrogen assimilation is more sensitive to environmental stresses. This trend was established irrespective of water regimes. Leaf P content at the end of drought period increased markedly when the P supply increased from P0 to P100 mg/kg soil. Adequate P nutrition increased the content of P in leaves, stems and roots by 34, 46 and 53% respectively

Phosphorus contents in nodules were less changed by fertilizer application. Therefore, nodules had a tolerance to P deficiency. Our results were confirmed in other studies (Tang C.X. et al. 1992, Al-Karaki, G. N., et al. 1996).

In contrast, P content in the plant parts was reduced by P deprivation in both cultivars. Total P amount in Zodiac was lower than in Licurici. Supplemental Fe nutrition together with N application had a trend to increase the plant capacity to acquire more nutrients from soil under water stress conditions. But micronutrient application with P in normal water conditions reduced the P concentration in plant parts (fig.1). Therefore, it has observed an antagonism between these nutrients.

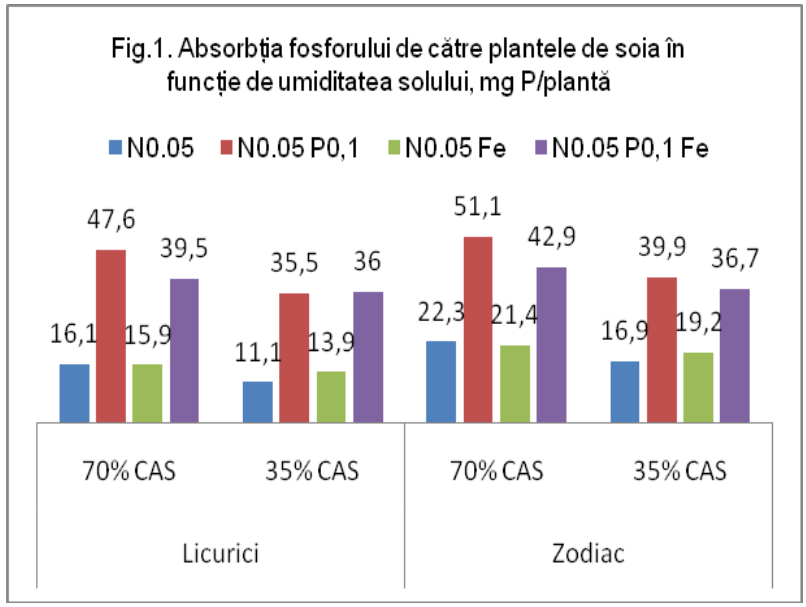

Fig.1. Absorbția fosforului de către plantele de soia în funcție de umiditatea solului, mg P/plantă

The same results were observed in other investigations (Shahandeh H. et al., 2003). It is important to note that higher P efficiency was observed in treatment with application of P and Fe. Hence, the adequate soybean nutrition with P positively marked metabolic processes that maintained plant production at normal level.

CONCLUSIONS

Drought stress reduced significantly the production of plant assimilates and its negative impact is more evident in low soil P fertility. There was a significant response of plant production to increasing phosphorus nutrition at both water regimes. Adequate phosphorus and iron supply diminished partially the negative influence of drought and increased soybean productivity.

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