PLANT GROWTH AND SOME PHYSIOLOGICAL RESPONSES TO PHOSPHORUS SUPPLY OF SOYBEAN (*GLYCINE MAX.L*) UNDER SUBOPTIMAL SOIL WATER REGIME

CREŞTEREA PLANTELOR DE SOIA (*GLYCINE MAX.L)* ŞI UNELE REACŢII FIZIOLOGICE LA APLICAREA FOSFORULUI ÎN CONDIŢII SUBOPTIMALE DE UMIDITATE

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Abstract. *Phosphorus (P) application is a common practice for improving crop production in soil with P deficiency and to reduce environmental stresses. A greenhouse experiment was conducted on soil to evaluate response of P application and water regimes in a factorial combination on growth, phosphorus concentrations and uptake by soybean (Glycine mx L.) plants. Soybean (cv Zodiac) plants were grown in a soil very low in available P. P application significantly increased dry weights of plants and leaf area. Plants at P deficiency and low levels of P supply had lower growth rates, nitrogen and P concentrations in plant tissues than plants grown at adequate supply (100 mg P kg^{-1} soil). Maximum dry weight of plants and nutrient uptake were obtained at 100 mg P kg^{-1} soil under normal water regime (70% WHC) and suboptimal level (35% WHC). Hence, adequate P nutrition maintained greater DM, leaf area and P uptake under drought conditions.*

Key words: plant growth, *Glycine max L.,* leaf area, phosphorus, suboptimal water regime.

Rezumat. *Aplicarea fosforului contribuie la sporirea productivităţii plantelor de cultură pe solurile cu deficit de fosfaţi mobili şi reduce impactul negativ al factorilor stresogeni de mediu. S-a efectuat o experienţă în condiţii căsuţei de vegetaţie pentru a evalua reacţia plantelor de soia la aplicarea fosforului în condiţii suboptimale de umiditate. Plantele de soia (cv Zodiac) au fost crescute pe un sol cu un conţinut inferior de fosfaţi accesibili pentru plante. Administrarea fosforului a sporit semnificativ masa uscată a pantelor şi suprafaţa foliară. Plantele fără aplicarea P precum şi celea ce au fost fertilizate cu doze mici au înregistrat rate joase de creştere precum şi de acumulare a P. Acumularea maximă de substanţe organice s-au înregistrat în varianta cu aplicarea 100 mg P kg^{-1} sol indiferent de nivelul de umiditate a solului. Deci, efectuarea nutriţiei suplimentare cu P atât în condiţii optimale, cât şi insuficiente de umiditate contribuie la menţinerea creşterii plantelor, asigură o suprafaţă de asimilare mai mare şi menţine productivitatea plantelor la un nivel mai ridicat.*

Cuvinte cheie: creşterea plantelor, *Glycine max* L., suprafaţa foliară, fosfor, umiditate suboptimală.

INTRODUCTION

Phosphorus (P) deficiency is a common problem in many soils (Marschner, 1995) and it is considered a major constraint for the production of legumes in majority of agricultural regions. Among plant nutrients, P is one of the important macronutrients controlling plant growth and development, and has a vital role in the large range of physiological processes (Raghothama, 1999). It was reported that insufficient P nutrition can affect cell division in growing tissues and restrict expansion growth of organs (Chiera et al., 2002), increase ABA translocation in the xylem and reduce translocation of nitrate to sink organs. Positive effects of P application on plant performance under stress environments have been reported in chickpea (Samiullch and Fatma, 1995), clusterbean (Burman et al., 2009).

It is well established that legumes, in particular soybean, in comparison with other species required high P nutrition level. Nutrient uptake and use efficiency is controlled not by plant heredity but by other abiotic constraints especially by water availability in soil. Mineral nutrient availability and uptake are adversely affected by low soil water level (Atkinson, 1985).

In many agricultural regions P deficiency is often accompanied by shortage of soil moisture. Inadequate water regime has a negative impact and affects both vegetative and reproductive growth of plants resulting in essential yield losses. According to research of *Desclaux et al*., (2000) soybean is very sensitive to water shortage during reproductive stage development. Evidence in the literature suggests that drought tolerance of cotton, white clover is enhanced by stimulated root growth and root functioning in response to increased P supply (Radin and Eidenbock, 1984, Singh and Sale, 2000). Although these environmental factors are extremely important in cropping systems as a rule in majority of cases they have been studied separately. Hence, the objective of present research was to examine the effects of P application on biomass production, leaf area development and P uptake of soybean plants in relation to soil water regime.

MATERIAL AND METHOD

A pot experiment was conducted in a glasshouse with P deficiency soil. Treatments included the factorial combination of four P levels and two soil water regimes (control and water stress). There were four P application rates namely as 0, 10, 20 and 100 mg P kg^{-1} soil which were termed as P deficiency (P0), low phosphorus (P10), moderate low P (P20), and higher P (P100). All pots with P application received potassium (K) as KCL to equivalent potassium level. Each pot was filled with 6 kg soil of P deficient soil that was sieved before. The content of available phosphorus was 4.4 mg kg^{-1} (CAL method). Soybean seeds (cultivar Zodiac) were treated with *Bradyrhizobium japonicum* at sowing time and after emergence plants were thinned to three per pot. The water treatments were 70% water holding capacity (WHC) as normal level and 35% WHC as stress drought. The all plants were grown till 4 weeks at normal water regime (70% WHC). Suboptimal moisture of soil was imposed to half of plants for 2 weeks after 4 weeks of growth. At harvest plants were separated into leaves, stem plus petioles, roots and nodules and leaf area was determined**.** The ground materials were dry-ashed at 550 C for overnight and the concentration of P was determined using molybdovanadate yellow method. Total N concentration in the plant parts ground was determined on a 50 mg-sample using the vario MAX CNS analyzer (GmbH, Germany).

RESULTS AND DISCUSSIONS

Dry matter (DM) production of soybean plants was significantly inhibited by both abiotic factors P deficiency and water shortage (fig. 1). However the amount of DM was reduced by P deficiency more evidently than by water stress.

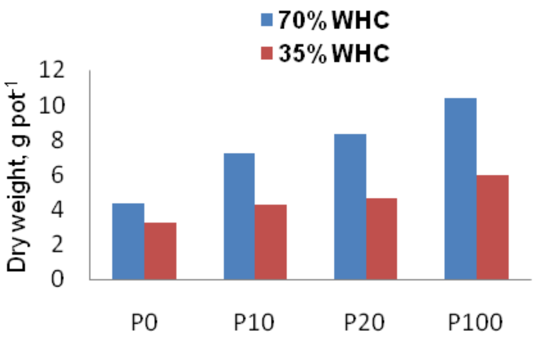

Fig.1 Growth response of cv Zodiac to different P treatments (mg P kg^{-1} soil) in relation of soil water regime

Under P deficiency the reduction in DW was 39.5% against low P supply. Plant growth responded more significantly to P fertilization in normal of water regime (70% WHC). Cultivar Zodiac gave the highest response to P application with plant weight at P0 being only 60.5% and 54.5% of the maximum yield at P100 at normal and water stress. Likewise, water regime affected the pattern of biomass partition within plant organs. Dry weights of roots were also lower at P0 as compared with treatment 100 mg P, but the decrease in root weight by P deficiency was less than the nutrient effect on shoots weight. High P level increased the root biomass and enabled plants to extract more water from drying soil for their growth. Leaf area development was very sensitive response of crop growth to P deficiency and water shortage. The values of leaves area in all treatments increased significantly with increasing P levels (fig. 2). The largest area was registered in plants receiving high level of P nutrition (100 mg P).

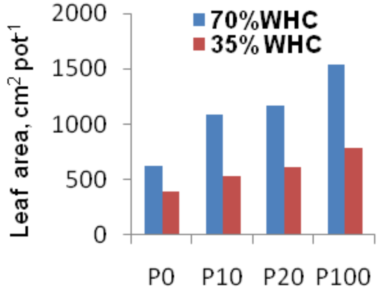

Fig. 2 Leaf area response of cv Zodiac to different P treatments...

The positive effects of P application were evident in both water regimes normal and stress (35% WHC). Suboptimal soil water regime reduced drastically leaf area. The lowest leaf area was observed under P deficiency and had lower value by 40,2 and 49,9% under well watered and stress treatments respectively compared with high P treatment. Drought diminished the leaf canopy approximately by twice regardless of P supply (fig. 2). Our results are consistent with investigations performed by Israel and Rufty (1988). In several studies (Guterez-Boem and Thomas, 1999, Chiera et al., 2002) have been demonstrated that P insufficient supply reduced leaf area of legumes, decreased the number of leaves and the relative leaf appearance rate.

Experimental data demonstrated that nutrient supply and water conditions affected considerably P concentrations and partitioning within plants. Leaves and roots P concentrations of plants grown with 100 mg P were higher than for plants grown at P deficiency.

Table1

The effect of P supply on P concentrations in leaves, stems and roots of soybean in relation of soil moisture level, mg P g^{-1} DW

Treatments	Leaves	Stems	Roots	Leaves	Stems	Roots
	70% WHC			35% WHC		
P0	1.04	0.62	1.56	0.98	0.57	1.26
P10	2.78	1.28	2.13	1.32	1.24	1.50
P20	3.08	1.43	4.07	1.85	1.13	1.64
P100	3.71	1.84	4.77	3.19	1.59	3.66

The addition of 100 mg P per kg soil increased roots P content by 48% with respect to the P0 in the drought stressed plants (table 1). It was emphasized that P partitioning could play an important role in determine P utilization efficiency. Vesteragr et al., (2006) found that DM production correlated positively with the P uptake. Likewise it was suggest that the translocation ability of P from roots to leaves blades during P deprivation could be used to select for low P-tolerant cultivars within species (Chaudhary and Fujita, 1998). The rates of P uptake by soybean plants were severely affected by P supply at two water regimes (fig. 3). Phosphorus-deficient plants showed low rates of P uptake value, than these of P-sufficient (P100) ones.

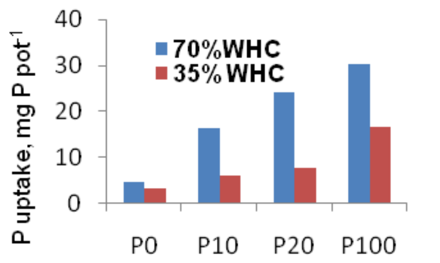

Fig. 3 Phosphorus uptake by soybean plants in relation to phosphorus supply and soil…

In this study it was observed that the rate of phosphorus use efficiency (PUE) was susceptible to soil moisture level. At high level of P treatment phosphorus PUE decreased by 3 times under water stress conditions compared to without P application treatment. Nitrogen concentrations in leaves and roots were affected by both factors P treatments and water regime (fig. 4).

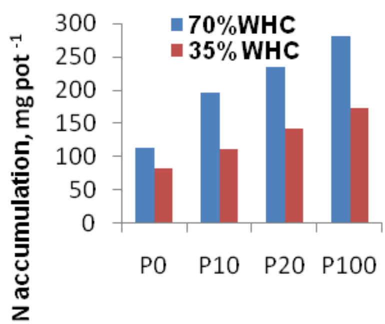

Fig. 4 Nitrogen accumulation by soybean plants in relation to phosphorus supply…

Phosphorus application increased significantly the rate of nitrogen assimilation. Stimulator effects of P supply were revealed in both water regimes. Total N accumulation during vegetative growth was 38,3% higher at 100 mg P kg^{-1} soil than at P0. The improved P status of several legumes solely dependent on symbiotic N fixation has been reported to increase tissue N concentration as well as overall host plant growth (Israel and Rufty, 1988). P insufficient supply (P0-P10) led to a decrease in whole plant N accumulation in particular under water low regime of soil. Hence, a comparison of the rates of N accumulation for control and water–deficit treatments showed significant differences irrespective of P supplemental nutrition.

CONCLUSIONS

Phosphorus application reduced adverse effects of low water regime on plant biomass production and selected physiological parameters of soybean cultivar. Results showed that there were significant growth, nitrogen and phosphorus partitioning in soybean plants in relation to P supply and soil moisture level demonstrating the requirement of adequate soil moisture for better growth of grain legume.

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