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Effect of biofertilizers and phosphorus on productivity and nutrient uptake of soybean (*Glycine max* L.)

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Soybean with an area of about 10 million hectare and production over 12 million tonnes is the most important oilseed crop. It builds up the soil fertility by fixing large amounts of atmospheric nitrogen through root nodules and also through leaf fall on the ground at maturity. Soybean, being the richest, cheapest and easiest source of best quality proteins (40%) and fats and also having a vast multiplicity of uses as food and industrial products, is sometimes called as wonder crop. Soils of mid hills of Himachal Pradesh are acidic in reaction. The acidic soil restrict the availability of phosphorus to the plants as phosphorus is locked up/ fixed up with the ions of Fe and Al. This adversely affects the growth and yield of the soybean. Micro organisms play key role in phosphorus availability to plants through mineralizing organic P in soil and by solubilizing precipitated phosphates (Richardson, 2001). Phosphorus is a major nutrient element in legume nutrition, as it is involved in several energy transformation and biochemical reactions including biological nitrogen fixation. The combined use of bioferilizers and inorganic source of plant nutrients, particularly phosphorus not only push the production and profitability of soybean but also help in maintaining the soil fertility. Keeping this in view, the present field study was undertaken to study the effect of biofertilizer and phosphorus on productivity and nutrient uptake of soybean.

The field experiment was conducted during *kharif*, 2011 at Experimental Farm of the Department of Agronomy, Forages and Grassland Management, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur. The experimental soil was silty clay loam in texture, having high organic C content (0.77%) with low in available N (280 kg/ha), medium in available P (21 kg/ha) and available K (160 kg/ha). Soil was acidic in reaction (pH 5.36). The experiment consisted of 16 treatment having combinations of two Rhizobium (with and without), two phosphorus solubilizing bacteria (with and without) and four phosphorus levels (0, 30, 45 and 60 kg P_2O_5/ha). These treatments were evaluated in a randomized block design with three replications. The plots were uniformly basal dressed with 20 kg N and 40 kg K_2O/ha and full quantity of phosphorus as per treatment at the time of sowing. Phosphorus solubilizing bacteria (PSB) cultures were mixed with FYM thoroughly and applied as per treatments. The seeds were treated with Rhizobium before two hours of sowing and sown in the evening. The soybean variety VLS-47 was sown using seed rate of 100 kg/ha and inter and intra-row spacing was kept at 30 x 10 cm. During crop season, 2039.6 mm rainfall was received. The estimation of oil content was determined by Soxhlet extraction method (A.O.A.C 1970).

Seed inoculation with Rhizobium recorded significant increase in plant height, nodules/ plant, pods/plant, grains/pod, stover and grain yield (Table 1). No significant improvement was observed in 1000- grain weight. The magnitude of increase in grain and stover yields were to the extent of 3.97 and 8.57%, respectively, over no inoculation. The increase in grain yield of

Table 1. Effect of *Rhizobium,* PSB inoculation and phosphorus fertilization on growth, yield and nutrient uptake of soybean

Treatments	Plant height (cm)	Nodules/ plant at flowering	Pods/ plant	Grains/ pod	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Oil content (%)	Oil yield (kg/ha)	Nutrient uptake (kg/ha) N	P	K
Rhizobium												
Non inoculated	75.8	47.2	52.1	3.5	135	1.76	3.38	18.3	324	89.5	7.78	29.4
Inoculated	78.6	50.6	65.0	4.0	136	1.83	3.67	18.8	347	99.1	9.62	31.8
CD (P=0.05)	1.5	1.5	1.7	0.1	NS	0.07	0.08	0.12	12.0	3.78	0.35	1.13
PSB												
No PSB	75.2	46.2	54.7	3.4	135	1.75	3.25	18.1	320	91.4	8.08	29.6
With PSB	79.1	51.6	62.4	4.1	136	1.84	3.80	19.0	351	97.2	9.32	31.6
CD (P=0.05)	1.5	1.5	1.7	0.1	NS	0.07	0.08	0.12	12.0	3.78	0.35	1.13
P levels (P_2O_5 kg/ha)												
Control	72.5	45.2	54.7	3.5	134	1.66	3.05	18.0	301	85.8	7.83	28.2
30	74.6	49.6	56.6	3.7	135	1.79	3.43	18.4	332	94.4	8.57	30.6
45	80.2	49.7	60.4	3.8	136	1.85	3.67	18.7	346	97.5	9.07	31.3
60	81.0	51.0	62.5	4.0	136	1.89	3.93	19.1	361	99.6	9.33	32.3
CD (P=0.05)	2.1	2.1	2.5	0.1	NS	0.09	0.12	0.16	17.0	5.35	0.50	1.59

soybean with Rhizobium inoculation may be attributed to root nodulation through better root development, more nutrient availability, resulting in vigorous plant growth and dry matter production which resulted in higher yield (Gaind and Gaur 1991).

Inoculation of soybean with PSB significantly increased the yield attributes (pods/plant, grains/pod), and yield. Inoculation of PSB increased the grain and stover yield by 5.14 and 16.92%, respectively, over control. PSB increased the availability of phosphorus to plants through solubilization effect and it is also known to produce vitamins and indole acetic acid (IAA) and gibberellins like substances. These growth factors in combination with better nutritional condition due to increased availability of P in soil might have played an important role in increasing the grain yield (Pramanik and Singh, 2003).

The graded enhancement of phosphorus application recorded significant increase in plant height, nodules/plant, pods/plant, grains/pod, yields and nutrient uptake. The highest dose of P (60 kg P_2O_5/ha) increased the grain and stover yield by 13.85 and 28.85%, respectively, over control. But, it was at par with 45 kg P_2O_5/ha. Yield is a function of yield attributing character (number of pods/ plant and number of grains/ pod), which were increased with the increase in P levels. The improvement in yield with increased supply of P might be due to profuse nodulation leading to increased nitrogen fixation which in turn had positive effect on photosynthetic organ resulting in higher grain yield (Pramanik and Singh 2003).

Inoculation of seed with *Rhizobium* and PSB improved oil content and oil yield. Application of 60 kg P_2O_5/ha increased the oil yield by 19.93% over control (301 kg/ha). Increase in oil content with biofertilizer and P application might be attributed to balanced nutrition and increased availability of nutrients. The supply of these nutrients seems to be involved in an increased conversion of primary fatty acid metabolites to end products of fatty acid by increased activity of acetyl co-A resulting in higher oil content (Hemantarajan *et al.* 2000). The higher oil yield was because of the increase in seed yield and oil content.

Total NPK uptake by soybean crop was significantly improved with inoculation of biofertilizers and Phosphorus application. Nutrients uptake was increased significantly with the increasing P level from 0 to 30 kg P_2O_5 /ha. This could be due to increased root nodulation through better root development and more nutrient availability, resulting in better absorption and utilization of all the plant nutrients (Singh and Pareek, 2003).

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