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Response of Different Sources of Phosphorus on Growth, Nodulation and Yield on Greengram (*Vigna radiata* L.)

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ABSTRACT

Phosphorus is a component of complex nucleic acid structure of plants and plays an important role in cell division, energy transformation and development of new tissue. Mung bean is a low altitude crop grown on a good loam soil with well distributed rainfall of 70–90 cm per year. In India, yields of mung bean ranging from 100 to 200 kg/ha have been reported. In the current study we have investigated the effect of phosphorus on growth, nodulation and yield of Green gram (Vigna radiata L.) in randomized block design with nine treatments replicated thrice. The results revealed that application of Single super phosphate (SSP) + phosphate solubilizing bacteria (PSB) seed inoculation produced significantly higher plant height. Our findings demonstrate that phosphorus plays important role in growth, nodulation of Vigna radiata L.

Key words: *Phosphorus, SSP, URP, PSB, Vigna radiata*

INTRODUCTION

Pulses are the main source of proteins particularly for vegetarians and contribute about 14 per cent of the total protein of average Indian diet. Production of pulses in the country is far below the requirement to meet even the minimum level per capita consumption. The per capita availability in pulses dwindling fast from 35.0 g/capita per day in 2005 as against the minimum requirement of 84 g per day per capita prescribed by ICMR, which is causing malnutrition among the growing people[2]. Green gram locally called as moong or mung [*Vigna radiata* (L.) Wilczek]. As it belongs to the family leguminaceae so it has the capacity to fix atmospheric nitrogen. It's one of the important kharif pulse crops of India which can be grown as catch crop between rabi and kharif seasons. India alone accounts for 65% of its world average and 54% of the total production. It is grown on about 3.50 mha in the country mainly in Rajasthan, Maharashtra, Andhra Pradesh, Karnataka, Orissa and Bihar. A phenomenal increase in area, production and productivity has occurred since 1964-65. The area has increased from 1.99 million ha in 1964-65 to 3.54 million ha in 2010-2011.

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The production has increased from 0.60 million tonnes to 1.81 million tons during the same period. Throughout the India, the Moongbean is used for different purposes. The major portion is utilized in making *dal*, soup, sweets and snacks[2].

Indian soils are poor to medium in available phosphorus. Only about 30 per cent of the applied phosphorus is available for crops and remaining part converted into insoluble phosphorus[6]. Phosphorus fertilization occupies an important place amongst the non-renewable inputs in modern agriculture. Crop recovery of added phosphorus seldom exceeds 20 per cent and it may be improve by the judicious management. As the concentration of available P in the soil solution is normally insufficient to support the plant growth, continual replacement of soluble P from inorganic and organic sources is necessary to meet the P requirements of crop[25]. P is added extra dose in recommended dose of phosphorus which increase nitrogen fixation and finally improve productivity of green gram[17]. It plays an important role in virtually all main metabolic processes in plant including photosynthesis, energy transfer, signal transduction, macromolecular biosynthesis and respiration[28].

Soil nutrition capacity of Single Super Phosphate (SSP) was further enhanced by PSB inoculation due to its capability to convert scarcely soluble inorganic phosphate into soluble forms through secreting organic acids[6]. Phosphorus application mix with phosphate solubilizing bacteria (PSB) and superior phosphorus uptake by plants and yields indicating that the PSB are capable to solubilize phosphates and then after mobilize phosphorus in plants[1]. In this respect, biofertilization technology has taken a part to decrease production costs and at the same time avoid the environmental hazards[4].

Rock phosphate (RP) is the single source for manufacturing phosphatic fertilizers. Unfortunately, India does not have adequate reserves of RP, and those present are mainly of low grade[18]. In India, deposits of rock phosphate (RP) are available but most of which are incompatible for using in the industry. Being a water insoluble source of P its availability in neutral to alkaline soils is very poor. Certain phosphate dissolving microorganisms (PDM) could be used as a means to improve the efficacy of rock phosphate and superphosphate[29]. Natural rock phosphates have been recognized as a valuable alternative for P fertilizers, the modern agriculture being dependent on phosphorus derived from phosphate rock. However, the direct application of low-grade rock addition for inoculums of phosphate solubilising microorganisms to soil has also been found to improve the rock phosphate efficiency as a phosphorus source. Most of the soil microorganisms, including bacteria and fungi, are able to mobilize phosphorus from sparingly soluble rock phosphates, and they have an enormous potential in providing soil phosphates for plant growth. These organisms are ubiquitous but vary in density and mineral/rock phosphate solubilising ability from soil to soil or from one production system to another[20]. Phosphate solubilizing bacteria inoculation enhances the mineralization of organic forms of phosphorus and solubilization of inorganic phosphorus, improving the availability of native soil phosphorus to plants and thereby increase yield attributes resulting to higher grain yield[11].

MATERIALS AND METHODS

The experiment was carried out during *kharif* season year 2014 at Crop Research Farm, Department of Agronomy, Allahabad School of Agriculture, Sam Higginbottom Institute of Agriculture, Technology and Sciences, Allahabad (U.P.). Pre-sowing soil samples were taken from the depth of 15 cm with the help of an auger. The composite samples were used for the chemical and physical analysis. Soil texture was Sandy loam having ratio 58.50%, 25.10% and 16.40% of Sand, Silt and Clay respectively. The pH of soil water suspension was determined using Equipments pH meter as described by Jackson[9], pH of soil was 7.5 with 0.40% organic C (Organic carbon was estimated by wet digestion method of Walkley and Black[27]. Availability of N,P,K in soil was 240, 22.50 and 95 kg ha^{-1} respectively. Estimation of available N in soil samples was followed alkaline potassium permagnate method[17]. Available phosphorus was estimated by Olsen's method and flame photometric method of Toth and Prince[26] was followed for determination of potassium (Kg/ha) concentration. The experiment was laid out in randomized block design with three replications, having two sources of phosphorus that is single super phosphate (SSP) and Udaipur rock phosphate (URP) and seed inoculation of PSB was carried out. There were total 09 treatment combinations in which T_1 Control, T_2 100% Phosphorus through SSP, T_3 100% Phosphorus through URP, T_4 50% Phosphorus through SSP + 50% Phosphorus through URP, T_5 75% Phosphorus through SSP + 25% Phosphorus through URP, T_6 100% Phosphorus through SSP + PSB seed inoculation, T_7 100% Phosphorus through URP + PSB inoculation, T_8 50% Phosphorus through SSP + 50% Phosphorus through URP + PSB inoculation, T_9 75% Phosphorus through SSP + 25% Phosphorus through URP + PSB inoculation. The net plot size was 3 m x 3m. All other agronomic practices i.e. thinning, hoeing, eradication of weeds and irrigation was kept same for all treatments. Mungbean variety 'Samrat' was sown. Data of plant height (cm), number of branches of $plant^{-1}$, number of nodules of $plant^{-1}$, dry weight (samples were air dried and then kept in oven for 72 hours at 70^0 C recorded in gram per plant), CGR (Crop growth Rate = $W_2 – W_1/ t_2 – t_1$ denoted g m^{-2} day^{-1} Where, W_1 =dry matter production per unit area at time t_1, W_2=dry matter production per unit area at time t_2, t_1 =days to first sampling, t_2 =days to second sampling) , RGR (Relative growth rate (RGR) = $\log w_2 – \log w_1/ t_2 – t_1$ denoted in g g^{-1} day^{-1} Where, w_1= Initial dry weight of plant (g), w_2=Final dry weight of plant (g), t_1= Initial time period, t_2= Final time period) were carried out following the formulae of Hunt, number of pods $plant^{-1}$, number of grains pod^{-1}, test weight (g), seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), harvest index (Harvest index =Economic yield (kg ha^{-1})/ Biological yield (kg ha^{-1}) x 100 persent in percentage), benefit cost ratio determination using formula Benefit cost ratio = Net return (₹ ha^{-1})/ Total Cost of cultivation (₹ ha^{-1}), protein content(%)calculated by the formula, Protein (%) = N (%) x 6.25 where Nitrogen determination using method Nitrogen (%) =(Sample titre – Blank titre) x 0.05 N HCl x 14 x100 /Weight of sample x 1000. The nitrogen content of grains was analyzed by Micro-Kjeldahl's method in grain. The data collected was subjected to the Fisher's analysis of variance (ANOVA) technique and the treatment's means were compared with the table value of 'F' at 5% level of significance.

RESULTS AND DISCUSSION

Response of different sources of phosphorus

Growth characters: Growth parameters of mungbean, *viz.* plant height, number of branches $plant^{-1}$, number of nodules $plant^{-1}$, plant dry weight (g), CGR (g m^{-2} day^{-1}) and RGR (g g^{-1} day^{-1}) were influenced by different sources of phosphorus. In the Table: 1, At 60 DAS, there was significant difference between different treatments. Maximum plant height (75.87 cm) was obtained by the application of 100% P through SSP + PSB seed inoculation (T_6), which was 15.89% higher than the lowest value 65.47 cm in control treatment (T_1). Maximum number of branches (2.67 $plant^{-1}$) was recorded with application of 100% P through SSP + PSB seed inoculation (T_6), which was superior against lowest value of 1.73 $plant^{-1}$ in control treatment (T_1) resulted 54.34% increase. However, T_7 (100% P through URP+ PSB seed inoculation) was found statistically at par with T_6 (100% P through SSP + PSB seed inoculation). At 45 DAS, there was significant difference between different treatments. Maximum number of nodules (65.27 $plant^{-1}$) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 32.31% higher than the lowest value 49.33 $plant^{-1}$ in T_1 (control). However, T_7 (100% P through URP + PSB seed inoculation), T_8 (50% P through

SSP + 50% P through URP + PSB seed inoculation) and T_9 (75% P through SSP + 25% P through URP + PSB seed inoculation) were found statistically at par with T_6 (100% P through SSP + PSB seed inoculation). Maximum dry weight (30.89 g plant^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 38.52% higher than the lowest value 22.30 g plant^{-1} in T_1 (control). Maximum crop growth rate (45.00 g m^{-2} day^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 35.30% higher than the lowest value 33.26 g m^{-2} day^{-1} in T_1 (control). However, T_7 (100% P through URP+ PSB seed inoculation) was found statistically at par with T_6 (100% P through SSP + PSB seed inoculation). Maximum relative growth rate (0.201 g g^{-1} day^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 11.67% higher than the lowest value 0.180 g g^{-1} day^{-1} in T_1 (control). However, T_7 (100% P through URP+ PSB seed inoculation) was found statistically at par with T_6 (100% P through SSP + PSB seed inoculation).

Productivity: Number of pods plant^{-1}, Number of grains pod^{-1}, seed yield (kg ha^{-1}), stover yield (kg ha^{-1}), and test weight of mungbean increased significantly due to different sources of phosphorus. However, harvest index (%) was nonsignificantly increased due to different sources of phosphorus. Maximum number of pods (31.53 plant^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 54.56% higher than the lowest value 20.40 plant^{-1} in T_1 (control). Maximum number of grains (12.80 pod^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 29.69% higher than the lowest value 9.87 pod^{-1} in T_1 (control). However, T_7 (100% P through URP+ PSB seed inoculation) was found statistically at par with T_6 (100% P through SSP + PSB seed inoculation). Maximum test weight (44 g) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 15.09% higher than the lowest value 38.23g in T_1 (control). However, T_7 (100% P through URP+ PSB seed inoculation) was found statistically at par with T_6 (100% P through SSP + PSB seed inoculation). Maximum seed yield (1496.67 kg ha^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 32.45% higher than the lowest value 1130 kg ha^{-1} in T_1 (control). Maximum stover yield (2920 kg ha^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 28.07% higher than the lowest value 2280 kg ha^{-1} in T_1 (control). However, T_7 (100% P through URP+ PSB seed inoculation) was found statistically at par with T_6 (100% P through SSP + PSB seed inoculation). But there was no significant difference between different treatments. Maximum harvest index (33.89%) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 2.29% higher than the lowest value 33.13% in T_1 (control). The results revealed that there was significant difference between different treatments in protein content. Highest protein content 24.06% was recorded in treatment T_6 (100% P through SSP + PSB seed inoculation) which was 10.01% higher than the lowest value 21.87% in T_1 (control). However, T_7 (100% P through URP + PSB seed inoculation), T_8 (50% P through SSP + 50% P through URP + PSB seed inoculation), T_9 (75% P through SSP + 25% P through URP + PSB seed inoculation) and T_5 (75% P through SSP + 25% P through URP) were found statistically at par with T_6 (100% P through SSP + PSB seed inoculation). Maximum cost of cultivation (24764.65 ₹ha^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 8.93% higher than the lowest value 22734.65₹ha^{-1} in T_1 (control). Maximum gross return (71766.82 ₹ha^{-1}) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 32.26% higher than the lowest value 54260.00 ₹ha^{-1} in T_1 (control). Maximum net return (47002.17₹ha^{-1}) was obtained by the application of T_6 (100%

P through SSP + PSB seed inoculation), which was 49.09% higher than the lowest value 31525.35 ₹ha^{-1} in T_1 (control). Maximum benefit cost ratio (1:1.89) was obtained by the application of T_6 (100% P through SSP + PSB seed inoculation), which was 36.96% higher than the lowest value 1:1.38 in T_1 (control).

DISCUSSION

The probable reason for increasing plant height of T_6 (100% P through SSP + PSB seed inoculation), could be attributed to better proliferation of roots and increased nodulation due to increased phosphorus availability. Phosphorus encourage formation of new cells, promote plant vigour and hastens leaf development, which help in harvesting more solar energy and better utilization of nitrogen, which help towards higher growth attributes. The results are in conformity with the references[5,21,22,19]. Microorganisms with phosphate solubilizing potential increase the availability of soluble phosphate and enhance the plant growth by improving biological nitrogen fixation. Similar findings was reported by Kucey[14], Ponmurugan and Gopi[16] and Devi[6]. The probable reason for increasing yield and yield attributes of T_6 (100% P through SSP + PSB seed inoculation) is that Phosphorus play a primary role in photosynthesis by way of energy transfer and thereby increase photosynthetic efficiency resulting in increased availability of photosynthetes. These all together resulted in overall increase in yield attributes. Similar findings were reported by Pal and Jana[15]. This might be due to the presence of sulphur in SSP, which is involved in the synthesis of fatty acids and also increase protein quality through the synthesis of certain amino acids such as cysteine and methionine. It is evident from the results that sulphur had remarkable influence on protein content. Similar findings were also reported by Havlin[7] and Kandpal and Chandel[12]. Phosphate solubilizing bacteria are also capable of transforming soil phosphorus to the forms available to plant. Similarly, protein yield were also maximum with the treatment SSP+PSB. This was due to higher oil and protein content of seed as well as higher grain yield per unit area. Similar findings were reported by Devi[6] and Rathour[19].

Effects of phosphorus solubilizing micro-oranisms on economics was also found by Gaur (1990) on arhar, gram, soybean, lentil, pea, urd and other crops. The results obtained in the investigation are in line with the findings of Srivastava and Ahlawat [21] and Rathour[19].

Table 1: Response of different sources of phosphorus on growth characters of Greengram

Treatments	Plant height (cm)	Number of branches plant^{-1}	Number of nodules plant^{-1} (45DAS)	Plant dry weight(g)	CGR (g m^{-2} day^{-1})	RGR (g g^{-1} day^{-1})
T_1	65.47	1.73	49.33	22.30	33.26	0.180
T_2	71.47	2.13	59.40	26.10	38.89	0.191
T_3	68.76	2.20	55.80	25.22	37.11	0.188
T_4	67.53	2.13	54.47	24.63	36.45	0.187
T_5	69.57	2.07	51.20	25.36	37.69	0.189
T_6	75.87	2.67	65.27	30.89	45.00	0.201
T_7	74.40	2.47	64.33	29.30	43.77	0.199
T_8	73.28	2.27	63.33	27.94	41.75	0.196
T_9	72.35	2.13	63.60	26.88	40.11	0.193
F test	S	S	S	S	S	S
SEd (±)	0.316	0.092	1.08	0.37	0.86	0.002
CD (P= 0.05)	0.670	1.73	2.29	0.79	33.26	-

CONCLUSION

It may be concluded that among the different sources of phosphorus, (100% P through 250kg SSP) in combination with PSB seed inoculation was found to be the best for obtaining highest seed yield (1496.67 kg ha^{-1}), net return(₹47002.17 ha^{-1}) and benefit cost ratio (1.89) in green gram. Since the findings are based on the research done in one season under agro-ecological conditions of Allahabad it may be repeated for confirmation.

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