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Short Communication

Response of green gram [*Vigna radiata* (L) Wilczek] to application of biofertilizers and phosphorus

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ABSTRACT

The present study was carried out at the Crop Research Centre, Carrier Point University, Kota (Rajasthan), during the *kharif* season of 2020 and 2021 to assess the effect of phosphorus, rhizobium and phosphate solubilizing bacteria on growth and yield attributes of green gram. Significantly increase in growth, yield attributes and yield of green gram were recorded with the application of phosphorus 50 kg P_2O_5/ha. In case of biofertilizers (PSB, Rhizobium and PSB + Rhizobium), all growth and yield attributes and yield were increased significantly. However, among treatment combinations, the maximum values of these parameters were observed with 50 kg P_2O_5/ha + biofertilizers (PSB + Rhizobium) in comparison to all other treatment combinations. The net returns and B: C ratio were also higher under 50 kg P_2O_5/ha + biofertilizers (PSB + Rhizobium).

Key words: Biofertilizers, Economics, Green gram, Phosphorus, Yield

Pulses are not only protein source for humans, but also a valuable source of protein for livestock because the biomass from the pulses is utilised to feed the animals (Kishore *et al*., 2023). It has been important component of Indian agriculture enabling the land to restore fertility by fixing atmospheric nitrogen and adding organic matter through leaf fall and root biomass. Green gram [*Vigna radiata* (L) Wilezek] is one of the important pulse crops grown in arid and semi-arid regions of the country, belongs to the family Leguminoceae, which fixes atmospheric nitrogen and improves soil fertility by adding 25-40 kg N/ha. Being a short duration crop (55-70 days) and having wider adaptability, it can be grown in summer as well as in kharif season.

Phosphorus (P) is referred to as the 'Kingpin' in crop production and also a limiting factor in crop yield on more than 40% of the world's arable land. Phosphorus reserves are getting depleted at a faster rate and according to some estimates, there will be no soil P reserve left by the year 2050. The deficiency of P is one of the greatest causes of concern in agricultural production (Lynch and Brown, 2008). In most of cases, P applied in the form of fertilizer gets absorbed by the soil quickly and is not available for utilization by the crop plants (Pallavi *et al*., 2022). As per an estimate, only 25 to 30% of the applied P is available to the crop plants and the remaining P is converted into insoluble P. Phosphorus is an important macronutrient required by the plants right from the seedling stage to maturity. P deficiency is one of the most important factors responsible for the poor yield of green gram in all types of soil. It is an indispensable constituent of the nucleic acids, ADP and ATP. It causes beneficial effects on nodule stimulation, root development and growth, hastens maturity, and improves the quality of crop produce.

Biofertilizers are a component of integrated nutrient management and are considered an eco-friendly, cost-effective and renewable source of non-bulky, low-cost plant nutrient supplementing fertilizer use in sustainable agriculture. The role of biofertilizers has significance in the present context of the very high costs of chemical fertilizers. Application of phosphatic fertilizers along with PSB is found to solubilize phosphate in the soil and increase the phosphorus uptake by plants, thereby positively influencing the crop yield (Tagore *et al*., 2013). Considering the above facts, the present study was conducted to findout the effect of application of P and biofertiliers on growth and productivity of green gram.

A field experiment was conducted during the kharif season of 2020 and 2021 at the crop research centre, Career Point University, Kota (Rajasthan). The soil was silty clay in texture, having a pH of 7.9, organic carbon of 0.57%, available P (16.7 kg/ha), total N (232.5 kg/ha) and available K (27 kg/ha).

The experiment was conducted in a Randomized Block Design with four replications. The treatments comprised of four levels of each phosphorus (0, 30, 40 and 50 kg P_2O_5/ha) and biofertilizers (control, PSB, rhizobium and PSB+rhizobium). A starter dose of N at 20 kg/ha and 40 kg K_2O were common for all the treatments. The variety 'Pusa Baishakhi' of green gram was used at a seed rate of 20 kg/ha. Seeds were inoculated with biofertilizers as per treatment before sowing. The seeds were sown in a line a planting geometry of 30 x 10 cm. The observations on different parameters recorded following the statandard protocol. The economics was computed on the basis of prevailing market price of inputs and outputs for each treatment. The total cost of cultivation of crop was calculated on the basis of different operations performed and materials used for raising the crop including the cost of fertilizers and seeds. The cost of labour incurred in carrying out different operations was also included. Statistical analysis of the data was done as per the standard analysis of variance technique for the experimental designs following SPSS software based programme, and the treatment means were compared at $P<0.05$ level of probability using t-test and calculating LSD values.

The experiment was conducted to assess the combined impact of P-levels and biofertilizers on various plant parameters in green gram. Regarding P-levels, a clear trend was observed where increasing P_2O_5 application (from 0 to 50 kg/ha) led to a gradual improvement in nodulation metrics, plant height, pod production, leaf area index (LAI), chlorophyll content, and dry matter accumulation. The highest P level (50 kg P_2O_5/ha) resulted in the maximum values for nodule/plant (33.5), effective nodules/plant (27.6), plant height (62.3 cm), pods/plant (20.8), LAI (3.53), chlorophyll content (4.52 mg/g), and dry matter accumulation (4712 kg/ha) (Table 1). These results were in conformity with Yadav *et al*. (2017). These findings suggest a positive correlation between phosphorus levels and enhanced growth and productivity in green gram. The observed increase in nodulation metrics, plant height, pod production, leaf area index, chlorophyll content, and dry matter accumulation with higher P-levels can be attributed to the crucial role of P in fundamental physiological processes (Yadav and Tarafdar, 2010). Phosphorus promotes root and shoot development, contributing to enhanced nodulation, increased plant height, and improved reproductive processes, thereby boosting pod production. Besides improving nodulation, the higher canopy development under the influence of upgrading the P-level seems to have enhanced absorption and utilization of energy (radiant), resulting in higher total and effective nodules (Barrios *et al*., 2014). As a key component of chlorophyll, phosphorus facilitates efficient photosynthesis, leading to higher chlorophyll content and an expanded leaf area index. These factors collectively contribute to greater dry matter accumulation, highlighting the essentiality of phosphorus in optimizing growth, development, and productivity in pulse crops.

Additionally, biofertilizer application also played a significant role in influencing plant parameters. Among the biofertilizers, the combined application of PSB (Phosphate Solubilizing Bacteria) and Rhizobium showed the most substantial impact, resulting in the highest values for nodule/plant

Table 1. Effect of P level and biofertilizers application on different plant parameters

Treatment	Nodule/ plant	Effective nodules/ plant	Plant height (cm)	Pods/ plant	Leaf area index	Chlorophyll content (mg/g)	Dry matter accumulation (kg/ha)
Phosphorus levels (kg P_2O_5/ha)							
0	25.4	19.4	46.3	12.5	2.11	3.22	3188
30	31.1	21.4	53.7	15.3	2.84	3.72	4089
40	32.0	24.3	58.3	19.6	3.49	4.31	4432
50	33.5	27.6	62.3	20.8	3.53	4.52	4712
SEm ±	0.8	0.7	1.3	0.4	0.09	0.08	79
CD (p=0.05)	2.2	2.0	3.8	1.2	0.26	0.23	225
Biofertilizers							
Control	26.5	20.1	46.9	14.3	2.02	3.46	3249
PSB	30.1	21.9	54.6	17.2	2.85	3.89	4029
Rhizobium	31.1	22.9	56.8	18.0	2.93	4.11	4338
PSB+Rhizobium	33.3	29.0	63.1	22.8	3.69	4.32	4929
SEm±	0.8	0.7	1.3	0.4	0.09	0.08	79
CD (p=0.05)	2.2	2.0	3.8	1.2	0.26	0.23	225

(33.3), effective nodules/plant (29.0), plant height (63.1 cm), pods/plant (22.8), LAI (3.69), chlorophyll content (4.32 mg/g), and dry matter accumulation (4929 kg/ha) (Table 1). Rhizobium, known for its nitrogen-fixing capabilities, forms symbiotic relationships with the plant roots, enhancing nutrient availability, particularly nitrogen. This can contribute to increased nodulation metrics and, consequently, plant height, pod production, and leaf area index. PSB, on the other hand, solubilizes unavailable phosphates in the soil, making phosphorus more accessible to the plants. The combined action of *Rhizobium* and PSB likely created a favorable environment for the plants, optimizing both nitrogen and phosphorus uptake. This dual enhancement in nutrient availability synergistically influenced chlorophyll content and, subsequently, photosynthetic efficiency, leading to higher dry matter accumulation (Majengo *et al*., 2011). Overall, these findings underscore the importance of both phosphorus management and biofertilizer application for sustainable and productive greengram cultivation. The results were in conformity with Prasad *et al*. (2014), Chaudhary *et al*. (2015) and Sai Teja *et al*. (2022).

Table 2 presents the effects of P-levels and biofertilizers on the yield and economics of green gram cultivation. Regarding P-levels, a consistent increase in grain yield, straw yield, gross return, net return, and benefit-cost ratio (B: C ratio) is observed with higher P_2O_5/ha applications (ranging from 0 to 50 kg/ha). The highest P-level (50 kg P_2O_5/ha) resulted in the maximum grain yield (1456 kg/ha), straw yield (3245 kg/ha), gross return (INR. 74,465/ha), net return (INR. 55,685/ha), and B: C ratio of 2.97. Similarly, when comparing the highest P-level (50 kg P_2O_5/ha) to the control, there was a significant improvement, with a 53.7% increase in grain yield, 43.7% in straw yield, 53.3% in gross return, 82.7% in net return, and a 75.4% increase in the B: C ratio. These findings are in close conformity with the results of Mitra *et al*. (2006), Rathour *et al*. (2015) and Venkata Rao *et al*. (2017).

The consistent increase in grain yield, straw yield, gross return, net return, and benefit-cost ratio (B: C ratio) with higher P-levels, particularly at the highest application of 50 kg P_2O_5/ha, can be attributed to the pivotal role of phosphorus in critical physiological processes governing plant growth and productivity. Phosphorus is an essential component of adenosine triphosphate (ATP) and nucleic acids, playing a crucial role in energy transfer and DNA synthesis. As phosphorus availability increases, it promotes robust root development, enhances nutrient uptake efficiency, and stimulates reproductive processes, ultimately leading to increased grain and straw yields. The improvement in yield is attributed to an increase in root nodulation due to P application (Bhatt *et al*., 2013). Mandiwal *et al*. (2019) reported similar results on P and biofertilizers. The heightened nutrient availability and improved plant vigor result in a substantial rise in overall crop productivity, reflected in elevated gross and net returns. The higher benefit-cost ratio further underscores the economic viability of the 50 kg P_2O_5/ha treatment, emphasizing the positive correlation between phosphorus enrichment and enhanced green gram cultivation outcomes.

The application of biofertilizers exhibited a substantial impact, with the combined use of PSB

Table 2. Effect of P level and biofertilizers on yield and economics of green gram

Treatment	Grain yield (kg/ha)	Straw yield (kg/ha)	Gross return (INR/ha)	Net return (INR/ha)	B: C ratio
Phosphorus levels (kg P_2O_5/ha)					
0	930	2256	48,480	30,450	1.69
30	1250	2831	64,155	45,675	2.47
40	1345	3076	68,985	50,355	2.70
50	1456	3245	74,465	55,685	2.97
SEm ±	29	66			
CD (p=0.05)	87	196			
Biofertilizers					
Control	950	2295	49,475	31,275	1.72
PSB	1210	2810	62,450	43,750	2.34
Rhizobium	1315	3017	67,685	48,985	2.62
PSB+Rhizobium	1520	3396	77,780	58,580	3.05
SEm ±	29	66			
CD (p=0.05)	87	196			

and Rhizobium resulting in the highest values for grain yield (1520 kg/ha), straw yield (3396 kg/ha), gross return (INR. 77,780/ha), net return (INR. 58,580/ha), and B: C ratio of 3.05. Specifically, the grain yield increased by 60.0%, straw yield by 47.8%, gross return by 57.2%, net return by 87.2%, and the benefit-cost ratio (B: C ratio) by 77.3%. A similar trend was also observed by Pramanik *et al*. (2014) and Vanitha *et al*. (2014). Rhizobium enhances nitrogen availability, crucial for plant growth, while PSB solubilizes phosphates, improving P-uptake. This dual inoculation likely optimized nutrient availability, leading to increased grain and straw yields, improved nutrient-use efficiency, and enhanced economic returns. The synergistic effect of PSB and Rhizobium highlights the potential of biofertilizers in not only enhancing yield but also improving the economic viability of green gram cultivation.

In view of the results obtained from the present investigation, it could be concluded that for securing higher seed yield and realization of net returns in vertisol under south-eastern part of Rajasthan, the green gram crop should be fertilized with 50 kg P_2O_5/ha + biofertilizers (Rhizobium+PSB) in addition to recommended dose of nitrogen (20 kg N/ha).

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