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Response of biofertilizer and graded doses of phosphorus on mungbean (*Vigna radiata L.*) in an *Inceptisols* of western undulating zone of Odisha

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Abstract
The field experiments were conducted during *Rabi* season of 2024-25 at instructional farm of College of Agriculture, OUAT, Bhawanipatna, Odisha to evaluate the effect of biofertilizers (PSB and Rhizobium) and graded doses of phosphorus (0, 75%, 100% and 125% RDF of P_2O_5) on the performance of green gram (*Vigna radiate* L.). Loamy sand soil of the experimental field was medium available P_2O_5. Application of biofertilizers and graded doses of phosphorus caused marked improvement in plant height, nodules per plant, pods/plant, average seeds per pod, protein content, seed and haulms yields, N, P and K content in seed and haulm and nutrient uptake. Application of 125% P+PSB+*Rhizobium* significantly increased economic yield over control and it was significantly at par with 100% P+PSB+*Rhizobium*. Nutrient content and uptake in kernel and haulm of green gram crop was significantly improved in treatments of 100% P+PSB+*Rhizobium* over control and were at par with highest level of 125% P+PSB+*Rhizobium*. Due to application of biofertilizers and graded doses of phosphorus the nutrient use efficiency and apparent nutrient recovery of P increased in treated plots. It has been recorded that Phosphorus Use Efficiency (PUE) ranged between 8.6 and 15.2 kg yield advantage per kg of P added (highest being in 75% P+PSB+*Rhizobium*). Similarly, Apparent Phosphorus Recovery (APR) varied between 11.2 and 25.8 per cent (highest being in 75% P+PSB+*Rhizobium*). Supplementation of 100% P2O5+PSB+Rhizobium is recommended to attain significantly higher yield over sole application of recommended fertilizer of 20-40-40 kg of N: P_2O_5: K_2O in green gram crop in a loamy sand soils of medium P status. Biofertilizer and graded doses of phosphorus supplementation approach in green gram crop maintained favorable residual status of soil in terms of pH (soil reaction), organic carbon content available N, P and, K.

Keywords: Green gram, yield, protein content, nutrient uptake, nutrient use efficiency, biofertilizers, phosphorus

Introduction
In emerging nations like India, the expanding population's consumption of a diet deficient in protein poses a major risk. Protein deficiencies cause a number of illnesses, including kwashiorkor and malnutrition, which are commonly seen in today's populations, especially in women and children. Concerns regarding sustainable food production are also raised by the world's steadily declining soil fertility. Nutritionists claim that because pulses are a remarkable source of dietary proteins, they can help meet the demands of a population that is growing at an exponential rate. Mungbean (*Vigna radiata* L.) is a popular crop in the leguminous family that is high in protein. Mungbean provides a large quantity of energy (334 kcal) and is a rich source of protein (21-24 g), carbohydrates (56.72 g), fiber (4.11 g), fat (1.31 g), and minerals (3.48 g) including calcium (124 mg), phosphorous (326 mg) and iron (4.42 mg) (Gopalan *et al*., 2002; Dhakal *et al*., 2016) [10, 8]. Due to its short lifetime, which makes it appropriate for intense crop rotation, the crop is widely embraced by farmers. The majority of legume crops grown in India, including mungbean, are grown in marginal, poor and less fertile soils; a lack of organic and inorganic nutrients also contributes to the low yield (Kumawat *et al*., 2010) [15]. Furthermore, it is predicted that over 50% of the world's potential output is impacted by the growth of crops on difficult soils, such as acidic and alkaline soils. In addition to significantly affecting the healthy

soil environment, the overuse and inappropriate use of inorganic fertilizers without understanding integrated nutrient management exacerbates the decreased productivity (Bradl, 2004) [4].

A variety of strategies have been employed in recent years to maintain agricultural output and the most promising one is the integrated utilization of available nutrient resources. In the future, agriculture will depend heavily on the efficient management of crops, water, soil and land, as well as the balanced use of nutrients. Given the changing climate, an integrated approach to nutrient application, biofertilizers and manures not only maintains crop output but also guarantees better soil health (Babulkar, 2000) [1]. Reports on integrated nutrition management (INM) in mungbean and other crops are, nevertheless, scarce. Biofertilizers are living microorganisms of bacterial, fungal and algal origin. They have several modes of action and can be used either alone or in combinations. Leguminous crop root nodules help fix atmospheric nitrogen in the soil so that plants can use it when biofertilizers are applied. When applied to seed or soil, biofertilizers increase nutrient availability and yield by 10-25% without harming the environment or soil (Chirumella *et al*., 2023) [6]. By enhancing phosphorus availability through the solubilization and mineralization of inorganic and organic soil P pools, phosphorus-solubilizing microorganisms (PSM) contribute significantly to plant nutrition (Singh). The motile, aerobic, Gram-negative rods known as *Rhizobium* have peritrichous, bipolar or subpolar flagella. β-hydroxybutyrate makes up 40-50% of the dry weight of cells. Spores are not produced by them. Legumes' rhizobium-mediated nitrogen fixation makes up a sizable amount of all biological nitrogen fixation. Through a symbiotic relationship with the bacteria *Rhizobium*, the nodules on mungbean roots can fix nitrogen from the atmosphere (Mandale *et al*., 2021) [16].

Rhizobium and pulse plants work together to increase soil fertility and provide a low-cost nitrogen fertilization technique for legumes (Meena *et al*., 2014) [17]. The *Rhizobium* strain, plant species and environmental factors all affect how much nitrogen is fixed. Legumes play a vital function in preserving the nitrogen balance in the soil and are self-sufficient for their nitrogen needs due to nitrogen fixation. Additionally, they enhance the biological and physical characteristics of the soil, including bulk density and soil aggregate stability (Bahadur and Tiwari, 2014) [2]. Because *Rhizobium* and PSB inoculation together has the dual benefits of N fixation and P solubilization in green grams, it not only greatly improves growth characteristics and yield attributes but also produces a significantly higher yield than *Rhizobium* and PSB inoculation alone (Singh, 1998) [23]. Given the aforementioned information a field experiment titled "Response of biofertilizer and graded doses of phosphorus on mungbean (*Vigna radiata L.*) in an Inceptisol of Western Undulating Zone of Odisha " was carried out in Rabi 2024 at the College of Agriculture, OUAT, Bhawanipatna instructional farm in the Kalahandi district which is located in the Western Undulating Zone's agroclimatic zone of Odisha. The experiment was to investigate the effects of graded doses of phosphorus and biofertilizer on groundnut with the following objectives to evaluate the effect of graded doses of phosphorus and biofertlizers on growth, yield and nutrient uptake of mungbean and its impact on residual soil properties.

Materials and Methods

The physic-chemical properties of initial soil sample of the experimental plot have been presented in table 1. Soil was loamy sand in texture, neutral in reaction (pH 6.79) with soluble salts content of 0.055 dSm^{-1}. The organic carbon content was medium, $KMnO_4$ extractable N was low; Olsen's P and NH_4OAc-K were medium in status. $CaCl_2$ extractable S (kg ha^{-1}) and DTPA extractable Zn (mg Kg^{-1} soil) were also found to be low in status.

Table 1: Initial physic-chemical properties of the experimental plot

Parameters	Test value	Status
Soil type	Sand 78.0%	Loamy sand
	Silt 10.3%	
	Clay 11.7%	
pH	6.79	Neutral
EC(dSm^{-1})	0.055	Normal
Organic carbon (%)	0.61	Medium
$KMnO_4$ oxidisable N (kg ha^{-1})	192	Low
Olsen's P (kg ha^{-1})	12.6	Medium
NH_4OAc-K (kgha^{-1})	194	Medium
$CaCl_2$ extractable S (kg ha^{-1})	13.2	Low
DTPA extractable Zn (mg Kg^{-1} soil)	0.56	Low

The total rainfall in the months of growing period was only 7 mm with a single rainy day. There was not much change in maximum temperature which ranged from 31.30C to 31.9^{0}C also with the minimum temperature ranging from 19.6^{0}C to 22.9^{0}C. The average relative humidity was 78.1% during growing season. Mean sunshine hour during entire growing period was fairly averaged to 9.7 hr/day. More or less the weather was favorable during growing period. The crop was grown with assured irrigation facility.

During first week of January, the land was ploughed by tractor, well pulverized, weeds were removed and leveled. The layout of the experiment was done with 30 sub plots of 3.0 m x 2.0 m size each. It was undertaken with the provision of drainage channels. The layout was planned in randomized block design with ten treatments and three replications. Treatment details of the experiment have been described in table 2.

The greengram variety Shreejan of 60 days duration was sown in line with a seed rate of 30 kg per ha on 2nd week of January, 2025 with a row to row and plant to plant spacing of 20 cm and 10 cm, respectively. The test crop green gram received recommended dose of fertilizer of N-P_2O_5-K_2O @ 20-40- 40 kg ha^{-1} though Urea, DAP and MOP. Full dose of N, P and K were applied as basal at the time of sowing as per treatment details. Biofertilizers; PSB and *Rhizobium* were applied as seed inoculation @ 20g each per kg of seed. Hand weeding, inter row hoeing and thinning operation were carried out within 15 days after sowing and plant protection measures were carried out as and when required to raise a good crop.

Table 2: Treatment details of the experiment

Treatments	Description
T_1	Control
T_2	N+75% P_2O5+ K_2O
T_3	N+75% P_2O5+PSB+K_2O
T_4	N+75% P_2O5+PSB+*Rhizobium*+K_2O
T_5	N+100% P_2O5+ K_2O
T_6	N+100% P_2O5+PSB+ K_2O
T_7	N+100%P_2O5+PSB+*Rhizobium*+K_2O
T_8	N+125% P_2O5+K_2O
T_9	N+125% P_2O5+PSB+ K_2O
T_{10}	N+125% P_2O5+PSB+*Rhizobium* K_2O

Effective nodules were counted in each treatment at 7th week of plant age by uprooting randomly selecting 5 numbers of plants from each sub plots. Then plants were washed in clean water, effective nodules were counted, averaged and data were recorded. At 60 days of plant growth the fresh plant samples (5 No.) were collected from each sub plots treatment wise, average plant height was recorded; plants were washed thoroughly with de-ionized water first, dried under shade and kept in a labelled paper bag. Collected plant samples then oven dried in hot air oven at 70^0 C till a constant weight was obtained. Then the average dry weight per plant was calculated for record.

After full maturity (60 days), crop from each plot was harvested. Ten plants from each sub plot were selected randomly for count of average number of pods per plant and average number of seeds per pod treatment wise. Similarly, treatment wise pod samples and haulm were collected separately, sun dried and weight was recorded for haulm yield. Then seeds were separated from pod and weight was taken to calculate seed yield and seed index. Then harvest index was calculated taking economic yield and biological yield into account. Previously taken seeds from pods and plant samples were oven dried at 70^0C till a constant weight was obtained. Oven dried seeds and plant samples were powdered with the help of mixer grinder and stored in polythene bags for further chemical analysis of nitrogen, phosphorous and potassium.

Data with respect to soil as well as plant parameters for various treatments were analysed for variance following standard statistical procedure outlined by Gomez and Gomez (1984) [9]. Nitrogen content of plant sample and seed was determined separately by micro kjeldahl digestion method followed by distillation as outlined by Jackson (1973) [11]. Protein content in green gram seeds was calculated by multiplying seed N content with 6.25 factor (Choudhary *et al*. 2015) [7]. One gram each of haulm and seed were first pre-digested with 5 ml of concentrated nitric acid (HNO_3) separately and then digested with diacid mixture consisting of nitric acid and per chloric acid ($HClO_4$) in the ratio of 3:2. The clear digested materials were made up to 50 ml volume using 6 N HCl and were subsequently used for the analysis of P and K. The phosphorus in the plant sample was determined by Vanadomolybdo- phosphate yellow colour method in nitric acid medium outlined by Jackson (1973) [11] after di-acid digestion(HNO_3 and per chloric $HClO_4$). The potassium content of plant samples of the experiment was determined by flame photometer method after suitable dilution as outlined by Jackson (1973) [11]. The nutrient contents were multiplied with corresponding seed and stover yield which were then added to find out the corresponding nutrient uptake in kg per hectare. Then Harvest Index (HI), Nutrient Use Efficiency (NUE), Apparent Nutrient Recovery (ANR) calculated for compilation of the result.

Results and Discussion

Effect of biofertilizer and graded doses of phosphorus on yield and yield attributing characteristics of green gram crop

Data related to the influence of biofertilizer and graded doses of phosphorus on plant height, nodules per plant, number of branches per plant, pod length and plant dry matter weight number of pods/plant, number of seeds per pod, seed index, seed yield, haulm yield and harvest index have been presented in table 3. A positive influence of applied biofertilizer and graded doses of phosphorus was observed on plant growth parameters of green gram crop. Plant height of green gram crop at maturity under the influence of biofertilizer and graded doses of phosphorus was varied between 28.3cm and 33.3 cm, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Plant height increased with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 100% P+PSB+*Rhizobium*, 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the plant height significantly over rest of the treatments

Number of nodules per plant of green gram crop at 42 DAS under the influence of biofertilizer and graded doses of phosphorus was varied between 14 and 26, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Number of nodules per plant increased with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 100% P+PSB+*Rhizobium*, 125% P, 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the number of nodules per plant significantly over rest of the treatments. Average number of branches per plant of green gram crop at maximum growth stage under the influence of biofertilizer and graded doses of phosphorus was varied between 11 and 14, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Number of branches per plant increased with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 75% P+PSB, 75% P+PSB+Rhizobium, 100% P+PSB+*Rhizobium*, 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the number of branches significantly over rest of the treatments. Average pod length of green gram crop at maturity under the influence of biofertilizer and graded doses of phosphorus was varied between 4.8 cm and 5.9 cm, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Plant dry weight increased with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in all the treatment combinations are at par and increased the pod length significantly over control.

Oven dried average plant dry weight per plant of green gram crop at maximum growth stage under the influence of biofertilizer and graded doses of phosphorus was varied between 13.1 g and 14.9 g, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Plant dry weight increased

with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in all the treatment combinations are at par and increased the plant dry weight significantly over control. Average number of pods per plant of green gram crop at maturity under the influence of biofertilizer and graded doses of phosphorus was varied between 21 and 24, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Number of pods per plant increased with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 75%P+PSB+*Rhizobium*, 100%P+PSB, 100% P+PSB+*Rhizobium*, 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the number of pods per plant significantly over rest of the treatments having no inoculation of biofertilizer. Average number of seeds per pod of green gram crop at maturity under the influence of biofertilizer and graded doses of phosphorus was varied between 6 and 9, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Number of seeds per pod increased with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 100% P+PSB+*Rhizobium* and 125% P alone or in combination with biofertilizers are at par and increased the number of seeds per pod significantly over rest of the treatments. Seed index of green gram crop after harvest under the influence of biofertilizer and graded doses of phosphorus was varied between 22.5 and 27.3, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium*. There was no significant difference between all the treatment combinations so far seed index is concerned. Seed yield of green gram crop after harvest under the influence of biofertilizer and graded doses of phosphorus was varied between 447 kg ha^{-1} and 738 kg ha^{-1}, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium.* Seed yield increased with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 100% P+PSB+*Rhizobium*, 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the economic yield significantly over rest of the treatments.Haulm yield of green gram crop after harvest under the influence of biofertilizer and graded doses of phosphorus was varied between 1205 kg $ha^{-1}$and 1545 kg ha^{-1}, lowest being with control and highest with treatment 100% P+PSB. Haulm yield increased significantly with application of increased level of phosphorus in combination with PSB or Rhizobium or both over control. Harvest index of green gram crop after harvest under the influence of biofertilizer and graded doses of phosphorus was varied between 27.1 and 32.7, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium*. Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the harvest index significantly over rest of the treatments. Similar observations have also been reported by Mohammad *et al.* (2017) [19], Chaudhari *et al.* (2016) [5], Bairwa *et al.* (2012) [3] and Mir *et al.* (2009). According to them the combination of PSB and *Rhizobium* (60 kg P_2O_5 + PSB + *Rhizobium*) resulted in maximum yield, closely followed by 40 kg P_2O_5+ PSB + *Rhizobium*.

Influence of biofertilizer and graded doses of phosphorus on nutrient content, uptake, nutrient use efficiency, apparent nutrient recovery and protein content of green gram crop

The impact of biofertilizer and graded doses of phosphorus application on NPK concentration, uptake, by seed and haulm and extra nitrogen gain, protein content, nutrient use efficiency, apparent P recovery by the green gram crop have been presented in table 4. Nitrogen content was recorded in seed that varied between 2.57 and 3.33 percent (lowest in control and highest in 125% P+PSB+*Rhizobium* and in the stover the same varied between 1.04 and 1.31 per cent (lowest in control and highest in 125% P+PSB+*Rhizobium*). Biofertilizer and graded doses of phosphorus influenced nitrogen uptake by the crop positively. Such distribution of N in the plant resulted in its uptake of 11.5 to 24.6 kg ha^{-1} through seed and by the stover it varied between 13.4 and 20 kg ha^{-1}, lowest being with control and highest with the plot treated with 125% P+PSB+*Rhizobium.* The Total nitrogen uptake by the crop followed the order: 125% P+PSB+*Rhizobium* > 125% P+PSB> 100% P+PSB+*Rhizobium*> 125% P alone. Biofertilizer and graded doses of phosphorus nutrition of the green gram crop influenced its biological N_2 fixation capacity; hence gain in nitrogen varied considerably between 7.7 and 19.8 kg ha^{-1}, lowest with 75% P alone and highest 125% P+PSB+*Rhizobium*. The extra nitrogen gain by the crop followed the order 125% P+PSB+*Rhizobium* > 125% P+PSB> 100% P+PSB+*Rhizobium*> 125% P alone. The percent protein varied considerably between 16.1 and 21%., lowest in control and highest with 125% P+PSB+*Rhizobium*. The protein content of all treatments except 75% P and 75% P+PSB receiving biofertilizer and graded doses of phosphorus are significantly superior over control.

It has been recorded that phosphorus content in seed ranged between 0.71 and 0.79 percent (lowest in control and highest in 75% P+PSB+*Rhizobium* and in the haulm the same varied between 0.22 and 0.33 per cent (lowest in control and highest in 125% P+PSB+*Rhizobium*. Biofertilizer and graded doses of phosphorus addition influenced phosphorus uptake by the crop positively. Such distribution of P in the plant resulted in its uptake of 3.16 to 5.46 kg ha^{-1} through seed and by the haulm it varied between 2.78 and 4.97 kg ha^{-1}, lowest being with control and highest with the plot treated with 125% P+PSB+*Rhizobium*. The total phosphorus uptake by the crop followed the order: 125% P+PSB+*Rhizobium* > 125% P+PSB> 100% P+PSB+*Rhizobium* and these treatments are found at par. It has been recorded that Phosphorus Use Efficiency (PUE) ranged between 8.6 and 15.2 kg yield advantage per kg of P added (highest being in 75% P+PSB+*Rhizobium*). Similarly, Apparent Phosphorus Recovery (APR) varied between 11.2 and 25.8 per cent (highest being in 75% P+PSB+*Rhizobium*). Potassium content was recorded in seed between 0.89 and 0.97 percent (lowest in control and highest in 125% P+PSB+*Rhizobium* and in the haulm it was observed between 0.97 and 1.08 per cent (lowest in control and highest both in 100%P+PSB+*Rhizobium* and 125% P+PSB+*Rhizobium*). Biofertilizer and graded doses of phosphorus supplementation influenced potassium uptake by the crop positively. Such distribution of K in the plant resulted in its uptake of 3.98 to 7.16 kg ha^{-1} through seed and by the haulm it varied between 12.43 and 16.66 kg ha^{-1}, lowest being with control and highest with the plot treated with 125%

P+PSB+*Rhizobium* in case of K uptake in seed and plot treated with 100% P+PSB+*Rhizobium* in case of K uptake in haulm, respectively. The total potassium uptake by the crop followed the order: 125% P+PSB+*Rhizobium* > 100% P+PSB+*Rhizobium* > 125% P+PSB> 100% P+PSB and these treatments are found at par. The experimental results corroborated with Singh and Pareek (2003) [21] who observed that PSB and *Rhizobium* inoculation improved nitrogen and phosphorus absorption, boosting protein accumulation. The study found that applying phosphorus (P) at 40 kg P_2O_5 ha^{-1} significantly enhanced the nitrogen (N), phosphorus (P), and potassium (K) content and uptake in both seed and straw of mungbean compared to lower P levels. The effect was statistically similar to the 60 kg P_2O_5 ha^{-1} treatment. Specifically, 40 kg P_2O_5 ha^{-1} increased nitrogen content by 21.57% in seed and 30.85% in straw compared to the control, and by 6.28% in seed and 13.80% in straw compared to 20 kg P_2O_5 ha^{-1}. The increase in protein content is attributed to enhanced nitrogen and phosphorus uptake, which aids in amino acid and ATP synthesis, necessary for protein production. Similar findings were observed in previous studies by Khan *et al.*, 2002; Jain *et al.*, 2007 and Singh *et al.*, 2017 [13, 12, 22].

Influence of biofertilizer and graded doses of phosphorus on Residual soil physic-chemical properties

The experimental soil was neutral in reaction, with pH 6.79 at the initial stage. The pH had slightly increased after crop harvest in all the treatments with biofertilizer and phosphorus application practice. The pH was maintained in between 6.80 to 6.84 in the treatments with different combinations of biofertilizer and graded doses of phosphorus in spite of higher crop removal of bases. After harvest of the crop the organic carbon content was maintained in all the treatment combinations of biofertilizer and graded doses of phosphorus application practice. After harvest of the crop the available nitrogen content decreased slightly in control and plot receiving 75% P alone. However, biofertilizer and phosphorus applications maintained the nitrogen status in rest of the treatment practices.The available phosphorus content decreased slightly in control plot with no biofertilizer and phosphorus application, where as it was slightly increased in rest of the practices. After harvest of the crop the available potassium content decreased slightly in control plot with no biofertilizer and phosphorus application, where as it was slightly increased in rest of the practices.

Meena *et al.* (2014) [17] also reported that the symbiotic association between *Rhizobium* and pulse plants enhances soil fertility and serves as a cost-effective method of nitrogen fertilization in legumes. The amount of nitrogen fixed depends on the *Rhizobium* strain, plant species, and environmental conditions. According to Kokani *et al.* (2015), Nyekha *et al.* (2015) [20] and Mohammad *et al.* (2017) [19], during field experiments reported that the application of phosphorus improved the available P status of the soil after the harvest of green gram. Dhakal *et al.* (2016) [8] also observed that PSB inoculation significantly influenced the available P_2O_5 in soil after harvest.

Table 3: Effect of biofertilizer and graded doses of phosphorus on yield and yield attributing characteristics of green gram crop

Treatments	Plant height (cm)	Nodules/ Plant	No of branches /plant	Pod length (cm)	Plant dry weight (g)	No of Pods/ Plant	No of seeds/ pod	Seed index (g)	Seed Yield (kg/ha)	Stover Yield (kg/ha)	Harvest Index%
Control	28.3	14	11	4.8	13.1	21	6	22.5	447	1205	27.1
75% P	29.5	18	13	5.5	13.2	21	7	24.1	561	1353	29.3
75% P+PSB	29.6	19	13	5.5	13.7	22	8	24.6	575	1383	29.4
75% P+PSB+*Rhizobium*	30.6	23	14	5.7	13.8	24	8	25.1	648	1506	30.1
100% P	30.1	21	12	5.6	13.7	22	7	25.5	594	1419	29.5
100% P+PSB	30.4	22	12	5.7	13.8	23	8	26.1	666	1545	30.2
100% P+PSB+*Rhizobium*	32.7	25	13	5.7	14.2	24	8	26.8	708	1542	31.5
125% P	30.1	25	12	5.8	14.1	21	9	25.5	654	1506	30.3
125% P+PSB	31.1	25	13	5.9	14.8	23	9	26.2	708	1515	31.9
125% P+PSB+*Rhizobium*	33.3	26	14	5.9	14.9	24	9	27.3	738	1524	32.7
SE(m)	0.73	0.8	0.3	0.16	0.58	0.7	0.2	1.98	18.1	111.7	-
CD(p=0.05)	2.2	3	1	0.5	1.7	2	0.7	NS	54	338	NS

Table 4: Concentration and uptake of NPK and protein content of green gram crop

atments	N content in Seed (%)	N content in Stover (%)	N uptake in seed (kg ha^{-1})	N uptake in stover (kg ha^{-1})	Total N uptake (kg ha^{-1})	Extra N gain (kg ha^{-1})	Protein %	P content in Seed (%)	P Content in Stover(%)	P uptake in seed (kg ha^{-1})	P uptake in stover (kg ha^{-1})	Total P uptake (kg ha^{-1})	PUE= $\frac{Yt - Y0}{P}$	APR= $\frac{Ut - U0}{P} \times 100$	K content in Seed (%)	K Content in stover (%)	K uptake in seed (kg/ha)	K uptake in stover (kg/ha)
Control	2.57	1.04	11.5	13.4	24.9	-	16.1	0.71	0.22	3.16	2.78	5.94	-	-	0.89	0.97	3.98	12.43
75% P	3.04	1.14	17.1	15.4	32.5	7.7	19.0	0.75	0.24	4.19	3.23	7.42	8.6	11.2	0.91	1.00	5.11	13.53
% P+PSB	3.08	1.15	17.8	16.0	33.7	8.9	19.3	0.76	0.26	4.37	3.61	7.98	9.7	15.5	0.93	1.05	5.35	14.52
75% +*Rhizobium*	3.16	1.17	20.5	17.7	38.2	13.4	19.8	0.79	0.28	5.14	4.22	9.35	15.2	25.8	0.93	1.07	6.02	16.12
00% P	3.14	1.21	18.7	17.2	35.9	11.0	19.7	0.75	0.27	4.44	3.73	8.17	8.4	12.8	0.92	1.06	5.47	15.04
% P+PSB	3.19	1.17	21.3	18.2	39.5	14.7	20.0	0.77	0.26	5.15	4.09	9.24	12.5	18.9	0.93	1.07	6.19	16.53
100% +*Rhizobium*	3.19	1.22	22.6	18.9	41.5	16.6	20.0	0.76	0.27	5.34	4.27	9.61	14.9	21.0	0.94	1.08	6.65	16.66
25% P	3.22	1.22	21.1	18.4	39.5	14.7	20.1	0.79	0.28	5.15	4.32	9.47	9.5	16.2	0.95	1.05	6.22	15.82
% P+PSB	3.25	1.27	23.0	19.3	42.4	17.5	20.3	0.73	0.30	5.15	4.55	9.69	11.9	17.2	0.96	1.06	6.80	16.06
125% +*Rhizobium*	3.33	1.31	24.6	20.0	44.6	19.8	21.0	0.74	0.33	5.46	4.97	10.43	13.3	20.6	0.97	1.08	7.16	16.46
SE(m)	0.065	0.038	1.41	0.99	1.73	-	0.40	0.021	0.013	0.374	0.310	0.443	-	-	0.024	0.034	0.341	0.354
(p=0.05)	0.19	0.11	4.2	2.9	5.1	-	1.2	0.06	0.04	1.11	0.92	1.32	-	-	0.07	0.10	1.69	1.75

Conclusion

From the present experiment it has been concluded that Supplementation of biofertilizer and graded doses of phosphorus in treatment combinations of 100% P+PSB+*Rhizobium*, 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the plant growth parameters over rest of the treatments. Average number of seeds per pod of green gram crop at maturity under the influence of biofertilizer and graded doses of phosphorus was varied between 6 and 9, lowest being with control and highest with treatment 125% P+PSB+*Rhizobium* and was at par with 100% P+PSB+*Rhizobium*. 100% P+PSB+*Rhizobium*, 125% P+PSB and 125% P+PSB+*Rhizobium* are at par and increased the seed yield significantly over rest of the treatments. Biofertilizer and graded doses of phosphorus influenced total nitrogen uptake by the crop positively and it varied between 24.9 and 44.6 kg ha^{-1}, lowest being with control and highest with the plot treated with 125% P+PSB+*Rhizobium*. The Total nitrogen uptake by the crop followed the order: 125% P+PSB+*Rhizobium* > 125% P+PSB> 100% P+PSB+*Rhizobium*> 125% P alone. The total phosphorus uptake by the crop followed the order: 125% P+PSB+*Rhizobium* > 125% P+PSB> 100% P+PSB+*Rhizobium* and these treatments are found at par. Phosphorus Use Efficiency (PUE) ranged between 8.6 and 15.2 kg yield advantage per kg of P added (highest being in 75% P+PSB+*Rhizobium*). Similarly, Apparent Phosphorus Recovery (APR) varied between 11.2 and 25.8 per cent (highest being in 75% P+PSB+*Rhizobium*). The total potassium uptake by the crop followed the order: 125% P+PSB+*Rhizobium* > 100% P+PSB+*Rhizobium* > 125% P+PSB> 100% P+PSB and these treatments are found at par. Biofertilizer and graded doses of phosphorus supplementation approach maintained favorable residual status of soil in terms of pH (soil reaction), organic carbon content available N, P and, K.

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