RESEARCH PAPER

Influence Of Phosphorus Fertilization And Biofertilizer Inoculation On Nutrient Dynamics In Grain And Straw Of Green Gram (*Vigna Radiata* L.)

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Abstract

The present study evaluated the effect of biofertilizers and phosphorus levels on nutrient content, protein content, and protein yield in grain and straw during two consecutive years. Results revealed that combined application of PSB + Rhizobium significantly improved nitrogen and phosphorus content over sole inoculation treatments. The combined inoculation increased nitrogen content in grain by 13.8% and 13.76% over PSB during the first and second years, respectively, while straw nitrogen content also increased considerably. Application of 60 kg P ha^{-1} recorded the highest nitrogen and phosphorus content in grain and straw, remaining statistically at par with 40 kg P ha^{-1}. Phosphorus content in straw under 60 kg P ha^{-1} was about 40% higher than control. Potassium content in grain and straw was not significantly influenced by treatments, although higher values were observed with 60 kg P ha^{-1}. Protein content and protein yield were also maximized with PSB + Rhizobium along with 60 kg P ha^{-1}, showing more than 100% increase in protein yield over control. Enhanced nutrient availability, improved biological nitrogen fixation, and better phosphorus solubilization collectively contributed to higher nutrient uptake, protein synthesis, and overall crop productivity.

Key Words: Biofertilizer, PSB, Rhizobium, Phosphorus Nutrient content

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Introduction

Legumes play a significant role as a crucial supplier of dietary protein and possess the unusual capacity to maintain and regenerate soil fertility via the process of nitrogen fixation and incorporation of a substantial quantity of residues **(Semba *et al.,* 2021).** Leguminous crops contribute around 30 kg ha^{-1} of N into soil after harvest. According to the World Health Organization (WHO), the recommended dietary allowance (RDA) for protein is around 0.75 grams of protein per kilogram of body weight per day for adults Hruby and Jacques, 2021). However, according to Indian Council of Medical Research (ICMR), the recommended dietary allowance (RDA) for protein is 0.83g/kg/day for adults **(ICMR, 2024)**. The Indian Market Research Bureau (IMRB) suggests that protein deficiency in Indians is more than 80%, and as per the recent National Sample Survey, India has a declining per capita protein consumption in both urban and rural areas **(IMRB, 2021).** Fertilizers constitute a costly and essential input for securing higher yields. The prudent use of fertilizers with appropriate method and time of application is the prime importance in securing higher yield and economic returns **(Sapkota and Singh 2025) (Nkebiwe *et al.,*2016*)*** As a result, either more area must be planted with pulses or productivity must be enhanced to increase production. Biofertilizers are inexpensive, sustainable sources of plant nutrition that are used in addition to chemical fertilizers. Latent cells of effective strains of phosphate solubilizing and nitrogen-fixing microorganisms used for soil treatment are commonly referred to as biofertilizers or microbial inoculants. **(Kumar *et al.,*2022) (Giri *et al.,*2025)** They contribute to food security and food safety by enhancing the growth and productivity of pulse crops through various mechanisms. Biofertilizers, which are primarily composed of beneficial microorganisms, establish symbiotic relationships with host plants, such as pulses, to increase their nutrient uptake and overall production. Biofertilizers containing nitrogen-fixing bacteria like 3 Rhizobium *leguminosarum Symbiovar viciae* (for peas, lentils and broad beans), *Rhizobium* spp. (for common beans), *Mesorhizobium* spp. (for chickpeas), and *Bradyrhizobium* spp. (for other legumes) help pulses fix atmospheric nitrogen, reducing the need for chemical fertilizers and improving soil fertility **(Vishnu, 2022)(Kaur,2022)** (**Bahuguna *et al.*, 2025).** Additionally, biofertilizers containing phosphate-solubilizing microorganisms can unlock soil phosphorus fractions unavailable for plants, thereby improving nutrient availability and crop yields. The PSB converts the insoluble Phosphate into soluble forms by acidification, chelation, exchange reaction and production of gluconic acid (**Elhaissoufi et al., 2022**). It is well known that VAM fungi improve plant growth through increased uptake of relatively immobile nutrients such as P, Zn, Cu etc. under low fertility conditions and also increase the tolerance of plants against soil-borne diseases (**Pan & Cai, 2023**). The excessive use of chemical fertilizers has generated several environmental problems which can be tackled by use of bio-fertilizers, which are natural, beneficial

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and ecologically friendly and as a promising component of integrated nutrient supply system in agriculture. Agriculture system depends on many important manipulations and microbial activities appear to be a tremendous potential for making use of micro organisms in increasing crop production **(Khosravi, 2025**). Currently, a real challenge for the workers in the field of agricultural research is to completely stop or reduce the use of expensive chemical fertilizers which negatively affect the environment as well as human health **(Chowdhuri et al.,2025).** Considering the above-mentioned facts, a study to evaluate the effect of bio fertilizer consortium along with application of different levels of phosphorus is imperative to improve nutrient and protein content of green gram

Method and materials:

A field experiment was conducted during the 2022-2023 and 2023-24 Zaid crop research farm, IFTM University, Moradabad, Uttar Pradesh, India. The experiment site lies between 28° 16´ to 28° 21´ N, 78° 4´ to 79° E and 193meters above mean sea level, on sandy loamy soil, to evaluate the effect of biofertilizer and phosphorus on summer green gram (*Vigna radiata L.*). The experiment was laid out in a Factorial Randomized Block Design twelve treatments in different combination of control, rhizobium and PSB i.e. 20 kg of P_2O_5+ Rhizobium, 20 kg of P_2O_5 + PSB, 20 kg of P_2O_5 + Rhizobium +PSB, 40 kg of P_2O_5 + Rhizobium, 40 kg of P_2O_5 + PSB, 40 kg of P_2O_5 + Rhizobium+ PSB, 60 kg of P_2O_5 + Rhizobium, 60 kg of P_2O_5 + PSB, and 60 kg of P_2O_5 + Rhizobium + PSB along with three control samples soil . The soil of the experimental field was sandy loam in texture, well-drained, and uniform, with a neutral to slightly alkaline reaction (pH 7.3). It contained 0.48% organic carbon and had low to medium available nutrient status, with 230 kg ha^{-1} nitrogen, 15.3 kg ha^{-1} phosphorus, and 162 kg ha^{-1} potassium. The green gram variety Pant Moong-2 was sown on 12 March 2023 and 18 March 2024 during the respective Zaid seasons. Sowing was done in rows at a spacing of 30 cm × 10 cm (row × plant spacing),

The mungbean variety "Pant Moong-2" was sown on 12 March 2023 using seed 25 kg ha^{-1} with a spacing of 30 x 10 cm. The crop was harvest on 18 March 2024.As per the treatments seed were inoculated with PSB, Rhizobium, PSB + Rhizobium before sowing using a standard method and dried shade **(Paul *et al.*,1971).** Thinning was carried out at 10-20 DAS. A uniform basal dose of 20 kg N ha^{-1} was applied through urea to the soil. However, in control plot no fertilizer was applied. The phosphorus was applied through SSP and potassium. Significant difference of sources of variation was tested at the probability level of 0.05. The standard error of the mean (SEm±) and the Cd. value was indicated in the tables to compare the difference between the mean values

Parameter	Value	Method
Available N (Kg ha^{-1})	230	Subbiah and Asija (1956)
Available P (Kg ha^{-1})	15.3	Olsen et al. (1954)
Available K (Kg ha^{-1})	162	Jackson (1973)
Organic carbon (%)	0.48	Walkley and Black (1934)
pH (1:2.5)	7.3	Jackson (1973)

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Statistical Analysis:

The data collected for the two successive years were subjected to statistical analysis by using analysis of variance (ANOVA) suitable to Factorial Randomized Block Design. The Critical Difference (C.D.) was used to compare the treatment means at P = 0.05 level of significance.

Results and Discussion:

Nitrogen Uptake (Table 1)

Results:

During both years of the study (2022-23 and 2023-24), both application of biofertilizers and phosphorus application significantly affected the uptake of N by the grain, straw and total crop.

Among the biofertilizers, the combined application of PSB and Rhizobium recorded the highest nitrogen uptake by grain (43.48 and 45.34 kg ha^{-1}), straw (29.14 and 30.77 kg ha^{-1}), and total crop (72.62 and 76.11 kg ha^{-1}) in 2022-23 and 2023-24, respectively. This was followed by Rhizobium alone and then PSB alone. The difference between the treatments of biofertilizers was significant at 5% level of confidence as revealed by CD values.

With respect to phosphorus levels, the application of 60 kg P_2O_5 ha^{-1} resulted in the maximum nitrogen uptake by grain (42.88 and 44.78 kg ha^{-1}), straw (30.85 and 32.59 kg ha^{-1}), and total crop (73.73 and 77.38 kg ha^{-1}). This was statistically similar to 40 kg P_2O_5 ha^{-1} compared to 20 kg P_2O_5 ha^{-1} or control (no phosphorus). The lowest amount of nitrogen uptake in both years was for the control treatment.

Discussion:

The combined treatment of PSB and Rhizobium showed significantly higher N uptake which may be attributed to synergistic effect of the two biofertilizers. Rhizobium promotes biological nitrogen fixation and phosphate solubilizing bacteria (PSB) promotes the release of inorganic phosphorus that facilitates improved root development, nodulation and N assimilation by the crop. The increase in microbial activity probably resulted in increased nutrient solubilisation and assimilation efficiency.

The positive response to the higher rates of phosphorus, up to 60 kg ha^{-1}, suggests that phosphorus is an important factor in energy transfer (ATP), root growth and nitrogen metabolism. Proper phosphorus supply leads to good root growth, aiding in better exploration of soil volume by the root system for nitrogen uptake and the ability to carry out symbiotic nitrogen fixation. The lower uptake in the control treatment emphasizes the need for P fertilization even in the presence of biofertilizers. The results are in line with the proven effect of balanced nutrition on the efficiency of nutrient use in leguminous or field crop. This observation is consistent with the work of **(Janati et al., 2021), (Ríos-Ruiz et al., 2024) and (Gram, 2017)**.

Phosphorus Uptake (Table 2)
Results:
In both 2022-23 and 2023-24, both levels of phosphorus and biofertilizer treatments had significant effects on phosphorus uptake by grain, straw, and total plant.
In both years, the combined use of PSB and Rhizobium resulted in the highest amount of uptake of phosphorus by grain (4.81 and 5.11 kg ha-1), by straw (5.19 and 5.61 kg ha-1) and by total grain and straw (10.00 and 10.72 kg ha-1). This treatment was much better than the treatments involving only PSB and Rhizobium.
The highest doses of phosphorus (60 kg P_2O_5 ha^{-1}) led to maximum P uptake by grain (5.00 and 5.30 kg ha^{-1}), straw (5.65 and 6.10 kg ha^{-1}), and total crop (10.46 and 11.23 kg ha^{-1}), which were significantly more than the lower doses and control. The lowest values of phosphorus uptake were recorded in the control treatment (no phosphorus) for all the parameters and years. All differences were significant according to the CD (P=0.05) values.

Discussion:
This better performance in phosphorus uptake by the PSB and Rhizobium is attributed to the ability of PSB to solubilize soil phosphorus by producing organic acids and enzymes to liberate soil P from unavailable to available forms. Presumably the addition of Rhizobium increased both root nodulation and overall plant vigor resulting in increased need and thus absorption of phosphorus. This synergic effect allowed the whole nutrient acquisition capacity of the crop to be enhanced. The phosphorus level applied increased progressively with an increase in uptake up to 60 kg ha^{-1}, indicating a direct relationship between the supply of phosphorus and its uptake. The higher doses provide adequate soil solution levels, particularly in soils with a high level of phosphorus fixation. This increased uptake in the treatment group compared with the control group highlights the lack of phosphorus in the native soil to support the crop **(Singh and Brar 2022).**
The results clearly showed that Integrated use of chemical phosphorus along with efficient biofertilizers (particularly PSB and Rhizobium) improved not only phosphorus uptake but also the overall nutrient balance in the plant. This can alleviate reliance on high rates of chemical fertilizers, and still achieve similar or better crop production and soil health. The present findings are in close conformity with the results of **(Shome et al., 2022) and (Ghadge et al., 2020).**

Table No.1 Nitrogen uptake as affected by varying phosphorus levels and biofertilizer application at different stages of crop growth

S.N.	**Treatments**	**Nitrogen uptake by grain (kg ha^{-1})**		**Nitrogen uptake by straw (kg ha^{-1})**		**Total nitrogen uptake by crop (kg ha^{-1})**	
		2022-23	**2023-24**	**2022-23**	**2023-24**	**2022-23**	**2023-24**
a.	**Biofertilizer**						
1.	PSB	22.71	23.68	19.71	20.80	42.42	44.49
2.	*Rhizobium*	35.05	36.55	25.48	26.89	60.52	63.44
3.	PSB+*Rhizobium*	43.48	45.34	29.14	30.77	72.62	76.11
4.	SEm±	0.751	0.605	0.480	0.503	1.118	0.978
	C.D. (P=0.05)	2.162	1.740	1.380	1.447	3.218	2.815
b.	**Phosphorus levels (kg ha^{-1})**						
1.	20	30.07	31.36	21.86	23.07	51.93	54.43
2.	40	40.73	42.41	28.80	30.38	69.53	72.78
3.	60	42.88	44.78	30.85	32.59	73.73	77.38
4.	Control	21.30	22.22	17.60	18.58	38.90	40.79
	SEm±	0.867	0.698	0.554	0.581	1.291	1.130
	C.D. (P=0.05)	2.496	2.009	1.593	1.671	3.715	3.250

Table No. 2: Phosphorus uptake as affected by varying phosphorus levels and biofertilizer application at different stages of crop growth.

S.N.	**Treatments**	**Phosphorus uptake by grain (kg ha^{-1})**	**Phosphorus uptake by straw (kg ha^{-1})**	**Total phosphorus uptake by crop (kg ha^{-1})**

		2022-23	2023-24	2022-23	2023-24	2022-23	2023-24
a.	**Bio-fertilizers**						
1.	PSB	2.58	2.74	2.99	3.23	5.57	5.98
2.	*Rhizobium*	3.94	4.19	4.16	4.49	8.10	8.68
3.	PSB+*Rhizobium*	4.81	5.11	5.19	5.61	10.00	10.72
4.	SEm±	0.081	0.089	0.088	0.099	0.147	0.169
	C.D. (P=0.05)	0.233	0.256	0.254	0.285	0.424	0.486
b.	**Phosphorus levels (kg ha^{-1})**						
1.	20	3.35	3.59	3.50	3.70	6.70	7.18
2.	40	4.60	4.80	4.90	5.30	9.40	10.06
3.	60	5.00	5.30	5.65	6.10	10.46	11.23
4	Control	2.39	2.59	2.60	2.74	5.00	5.36
	SEm±	0.110	0.119	0.103	0.117	0.170	0.195
	C.D. (P=0.05)	0.299	0.310	0.293	0.330	0.490	0.561

Conclusion:

The study demonstrated the significant effect of the biofertilizer application and phosphorus levels on nitrogen and phosphorus uptake by grain, straw and total crop during the two consecutive years (2022-23 and 2023-24). The combined inoculation of PSB and Rhizobium recorded the highest nitrogen uptake of 72.62 and 76.11 kg ha^{-1} in 2022-23 and 2023-24, respectively, and also highest uptake of phosphorus of 10.00 and 10.72 kg ha^{-1} for 2022-23 and 2023-24, respectively among the biofertilizers. Likewise, the application of 60 kg P_2O_5 ha^{-1} was better, which recorded the greatest nitrogen (73.73 and 77.38 kg ha^{-1}) and phosphorus (10.46 and 11.23 kg ha^{-1}) uptake by the crop. The interaction effects further revealed that the combination of PSB and Rhizobium with 60 kg P_2O_5 ha^{-1} was most effective for nutrient uptake.

The results clearly showed that dual biofertilizer inoculation along with optimum phosphorus fertilization significantly enhanced nutrient acquisition efficiency. PSB and Rhizobium were used together, which not only improved the biological nitrogen fixation and phosphorus solubilization but also decreased the need for excessive application of chemical fertilizers.

Based on the findings, it is concluded that the integration of PSB and Rhizobium together with nutrient application rate of 60 kg P_2O_5 ha^{-1} is a sustainable and effective option for improving the N and P uptake and maintaining the soil health and environmental safety.

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