RESEARCH PAPER

"Impact of Phosphatic Fertilization and Bio-fertilizers on Yield and Quality Parameters of Summer Green Gram (*Vigna radiata* L.)"

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Abstract
Phosphate Solubilizing Bacteria (PSB) enriched biofertilizer has emerged as a promising eco-friendly alternative to conventional chemical fertilizers for enhancing phosphorus availability in soil. This study aimed to evaluate the efficacy of a PSB-enriched biofertilizer formulation using locally isolated strains and suitable carrier materials.
The experiment was conducted and represented through Factorial Randomized Block Design (FRBD). It comprises with twelve treatments, in which three treatments of biofertilizers (PSB, Rhizobium and PSB + Rhizobium) were taken. The experiment was conducted and represented through Factorial Randomized Block Design (FRBD) with 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. The findings highlight its potential as a component of integrated nutrient management strategies, as 60 kg P_2O_5 ha^{-1} significantly increased nitrogen (N), phosphorus (P), and potassium (K) content in both grain and straw, as well as protein content and protein yield. It can be stated, the combined application of PSB + Rhizobium recorded significantly higher NPK content in grain and straw, along with improved growth attributes and yield of green gram.
Keywords: Biofertilizer, Rhizobium, Nitrogen, Phosphorus, Potassium, PSB
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Introduction: - Mungbean (Vigna radiata L. Wilczek) is the third most important pulse crop of India after chickpea and pigeonpea. It is commonly known as greengram, monggo or mung and belongs to Leguminosae family. Mungbean takes less time to mature, can be cultivated during rainy seasons, (kharif), winter season (rabi) and summer season and fits well in existing cropping pattern of the country. Sometimes, grown as a catch crop between season of kharif and rabi and shows more per day productivity. Mungbean has nutritive value, digestibility and reasonable amount of vitamins and essential micronutrients (Akhtar *et al.,*2013 and Kumawat *et al.,* 2022). mungbean (*Vigna radiata* (L.) Wilczek) is India's third most important pulse crop, accounting for nearly 16 % of total pulse area.

Mung bean [*Vigna radiata* (L.) Wilczek] is one of the upsurging, highly economical, nutritive Asiatic leguminous crops. The crop is getting higher attention in terms of the consumption and production worldwide being an important source of amino acids, proteins, dietary fibre and unsaturated fatty acids. It possesses folate and iron in significant amount along with several phytochemicals. (Pathak *et al,* 2023)

A seed of mungbean is highly nutritious containing 24–28% protein, 1.0–1.5% fat, 3.5–4.5% fibre, 4.5–5.5% ash and 59–65% carbohydrates on dry weight basis and provide 334–344 kcal energy. Mungbean protein is considered to be easily digestible. (Mehandi e*t al.,* 2019 and Kim e*t al.,* 2025) Many health organisations worldwide have recommended increased intake of plant-based foods to improve the prevention of chronic diseases and to improve overall human health. As a result, a variety of plant-based functional foods have been introduced into health care programmes One such crop that has exhibited health benefits is mung bean [*Vigna radiata* (L.) (Anwar e*t al.,* 2007 Shen e*t al.,* 2018)

Biofertilizers are composed of living or dormant micro-organisms that are capable of fixing the atmospheric nitrogen (N), solubilizing/mobilizing soil nutrients, and secreting growth promoting compounds. Biofertilizers do not supply nutrients but rather enhance the growth of plants and availability of nutrients. They can be divided into four groups: N2-fixing biofertilizers (e.g., Rhizobium), phosgene oxime (e.g., Bacillus), cellulolytic and PGPR (e.g., Pseudomonas**)** (Naveed et al., 2015 and Shahzad et al.,2025).

Phosphorus (P) is an essential nutrient for all organisms, including higher plants (Westheimer, 1987 Elser 2012). P is an important structural element of DNA, RNA, ATP, as well as of the phospholipids in biomembranes, and plays pivotal roles in photosynthesis, energy metabolism, the regulation of a variety of biochemical reactions, and cell signaling (Mimura and Reid 2024)

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The plasma membrane of root cell contains Pi transporters which take up Pi into the cells in the form of orthophosphate (Pi, H2PO4−) (Liu 2021). However, in many natural ecosystems and arable lands, the amount of P is not sufficient to maximize plant growth (Neset and Cordell 2012) which significantly limits global agricultural production. Pi deficiency is a limiting factor for 40%–60% of the world's arable land (Cordell et al., 2009 and Liu 2021).

MATERIALS AND METHODS: -

A field experiment was conducted during the Zaid (summer) seasons of Two-year crop data 2022–23 and 2023–24 at the Crop Research Farm of IFTM University, located in Moradabad Uttar Pradesh India. The region falls under a sub-tropical climatic zone, characterized by hot summers and mild winters. The average annual rainfall ranges from 750 to 1,005 mm, with the majority received during the monsoon season (July–September). The mean annual maximum and minimum temperatures are 45.2°C and 18.5°C, respectively. During summer, temperatures rise sharply, with May being the hottest month (up to 43.5°C), while winters remain mild with temperatures ranging from 8.7°C to 16.6°C. 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 experiment was conducted and represented through Factorial Randomized Block Design (FRBD). It comprises with twelve treatments, in which three treatments of biofertilizers (PSB, Rhizobium and PSB + Rhizobium) were taken. The experiment was conducted and represented through Factorial Randomized Block Design (FRBD) with 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. The findings highlight its potential as a component of integrated nutrient management strategies, as 60 kg P_2O_5 ha^{-1} significantly increased nitrogen (N), phosphorus (P), and potassium (K) content in both grain and straw, as well as protein content and protein yield. It can be stated, the combined application of PSB + Rhizobium recorded significantly higher NPK content in grain and straw, along with improved growth attributes and yield of green gram.

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)

Soil Characteristics

The soil texture of the experimental field was sandy loam, uniform and well drained. The initial properties of the soil were: organic carbon 0.48%, available nitrogen 230 kg ha^{-1}, available phosphorus 15.3 kg ha^{-1}, available potassium 162 kg ha^{-1}.

The experiment was designed in a Factorial Randomized Block Design (FRBD) in which 12 treatments were replicated four times. Three levels of biofertilizers, four levels of phosphorus along with a control were used for the treatments

Biofertilizer treatments:

1. PSB (Phosphate Solubilizing Bacteria)
2. Rhizobium
3. PSB + Rhizobium

Phosphorus levels:

(1) 20 kg P_2O_5 ha^{-1}

(2) 40 kg P_2O_5 ha^{-1}

(3) 60 kg P_2O_5 ha^{-1}

(4) Control (0 kg P_2O_5 ha^{-1})

Production of Varieties and Sowing:
The variety of green gram (*Vigna radiata* L.) used in the experiment was Pant Moong-2. In both the years, sowing of the crop was done during the second fortnight of February. Sowing of the crop was carried out in the second fortnight of February in both the years. The agronomic practices recommended for summer green gram were adopted. The respective biofertilizers (Rhizobium and/or PSB) treatment was done before sowing the seeds. Single superphospate (SSP) was used to apply phosphorus at the sowing treatment doses. All plots were fertilized with a uniform rate of nitrogen (as recommended by the package of practices) and potassium.

Biofertilizer Inoculation:
The rhizobium and PSB was obtained from a standard source. Seed inoculation was done by mixing the seeds with the respective biofertilizer slurry (prepared using jaggery/gum arabic solution) and shade-drying before sowing.

Data Collection and Observations:
Growth attributes, yield attributes, yield (grain and straw), nutrient content (N, P, K) in grain and straw, protein content and protein yield were observed at proper growth stage by adopting standard method. Nitrogen was estimated by the Kjeldahl method, phosphorus using the vanadomolybdate method and potassium using the flame photometric method. Nitrogen content of grain was used for protein content, which was determined by multiplying by 6.25. Protein yield was calculated as the grain yield multiplied by protein content.

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:
The results from **Table 1** indicating that, the biofertilizer inoculation and phosphate fertilization have significant effect on nitrogen (N) increase in the crop (presumably chickpea or other legume) and protein synthesis.
By concentrating on the biofertilizer effect (2022-23 and 2023-24), the combined application of PSB + Rhizobium recorded the highest nitrogen content in grain (3.70% and 3.72%) and straw (1.14% and 1.15%), protein content (23.13% and 23.26%), and protein yield (271.74 and 283.38 kg ha^{-1}). In this case, inoculations were superior to this treatment statistically and compared with the implied control. On other hand, the biological nitrogen fixation activity of Rhizobium was superior to PSB alone as expected, since it is directly involved in BNF. Overall, it can be stated that, the differences between the means were statistically significant as determined by the C.D. values (e.g., for grain N: C.D. ≈ 0.184–0.186; and for protein yield: C.D. ≈ 11.44–14.74).
Simultaneously, in case of phosphorus, the contents of nitrogen, protein and protein yield increased with the increasing application of phosphorus till 60 kg P_2O_5 ha^{-1} and the highest values were recorded at 60 kg P ha^{-1} (grain N: 3.72–3.74%; protein: 23.25–23.38%; protein yield: 267.99–279.89 kg ha^{-1}). While, the control (contain no phosphorus) had the lowest measurement for all parameters. The P levels were significantly different from control and from each other, with good response of the crop to P application.
From the summary of the above findings, it can be stated that, a combination of dual biofertilizer inoculants and sufficient phosphorus fertilization significantly improved N uptake, protein synthesis and ultimately protein yield. Phosphorus was most likely responsible for better root development, nodulation and N fixation efficiency thus increasing the efficiency of N assimilation. The finding of the study aligns with Shome et al., 2022 and Janati et al., 2021.
Furthermore, **Table 2** demonstrating the effect of treatments on the concentration of phosphorus (P) in grain and straw over the period of 2 years. In which, considering the biofertilizer Effect, dual inoculation (PSB + Rhizobium) gave the highest level of phosphorus in both grain (0.41–0.42%) and straw (0.20–0.21%). In addition to these, PSB alone also enhanced the P content over the control/Rhizobium, however, the combination treatment was found the best. The differences were statistically significant (C.D. for grain P = 0.022; for straw P = 0.010). On the other hand, considering the phosphorus levels, with increasing phosphorus application, there was a significant increase in phosphorus content of the straw and grain. The maximum P content was observed at 60 kg P ha^{-1} (grain: 0.42–0.43%; straw: 0.21–0.22%) and the grain of the control treatment (0.36–0.37%) and straw (0.15–0.16%) had the lowest P concentration. The application of 40 and 60 kg of P ha^{-1} resulted in significantly higher P content than 20 kg and control.
Overall it can be stated from the findings from **Table 2**, biofertilizers (particularly PSB) and direct P fertilization were beneficial for P uptake and its distribution to grain and straw. The outcomes indicate that microbial solubilization (PSB) and phosphorus-induced root proliferation/nodulation have resulted in increased efficiency of phosphorus utilization. The finding of the study is close to the studies of Adnan and Bargaz with their respective research teams. (Adnan et al., 2017; Bargaz et al., 2021)
Apart from these, the effect of biofertilizers and phosphorus levels on potassium (K) nutrition has been shown in **Table 3** mainly focusing on biofertilizer Effect (2023-24) is considered. In which, the PSB + Rhizobium inoculation resulted in the highest level of potassium in grain (1.86–1.88%) and straw (1.30–1.31%). It was observed that, only Rhizobium was ranked second followed by PSB. The differences were statistically significant (C.D. for grain K ≈ 0.096–0.098; straw K ≈ 0.062–0.071). However, in case of

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phosphorus levels, the higher doses of phosphorus resulted in higher potassium levels. Apart from these, the highest K content was recorded at 60 kg P ha^{-1} (grain: 1.88–1.90%; straw: 1.31–1.32%). The K concentrations in the control treatment were significantly lower (grain: 1.72–1.74%; straw: 1.22–1.23%). From this finding, it was observed that, the phosphorus application at higher rates resulted in significant improvement of K uptake.

Comprehensively from the observation from **Table 3**, it can be stated that, there was a significant increase in potassium uptake with both biofertilizer inoculation and phosphorus fertilization, though the potassium was not applied directly. This indicates improved overall plant vigor, root activity, and possibly better cation exchange and transport mechanisms facilitated by better P nutrition and microbial activity. The finding supports the finding of Khoso and team. (Khoso et al., 2024)

Table 1: Nitrogen content in grain, straw and protein as affected by biofertilizers and phosphorus levels at successive stages of crop growth

S.N.	Treatments	2022-23				2023-24			
		Nitrogen Content (%)		Protein (%)	Protein Yield (Kg ha^{-1})	Nitrogen Content (%)		Protein (%)	Protein Yield (Kg ha^{-1})
		Grain	Straw			Grain	Straw		
a.	**Biofertilizer**								
1.	PSB	3.25	1.07	20.31	141.94	3.27	1.08	20.43	148.02
2.	*Rhizobium*	3.46	1.12	21.63	219.05	3.48	1.13	21.75	228.43
3.	PSB+ *Rhizobium*	3.70	1.14	23.13	271.74	3.72	1.15	23.26	283.38
4.	Sem ±	0.064	0.022	0.458	3.976	0.065	0.019	0.395	5.121
	C.D. (P=0.05)	0.184	0.062	1.317	11.440	0.186	0.054	1.137	14.735
b.	**Phosphorus levels (kg ha^{-1})**								
1.	20	3.46	1.10	21.63	187.95	3.48	1.11	21.75	196.00
2.	40	3.60	1.13	22.50	254.56	3.62	1.14	22.63	265.04
3.	60	3.72	1.16	23.25	267.99	3.74	1.17	23.38	279.89
4.	Control	3.10	1.05	19.38	133.15	3.12	1.06	19.49	138.85
	Sem ±	0.074	0.025	0.529	3.976	0.075	0.022	0.456	5.121
	C.D. (P=0.05)	0.212	0.072	1.521	11.440	0.215	0.063	1.313	14.735

Table 2: Phosphorus content in grain and straw as affected by biofertilizers and phosphorus levels at successivestages of crop growth

S.N.	Treatments	Phosphorus content in grain (%)		Phosphorus content in straw (%)	
		2022-23	2023-24	2022-23	2023-24
a.	**Biofertilizer**				
1.	PSB	0.37	0.38	0.16	0.17
2.	*Rhizobium*	0.39	0.40	0.18	0.19
3.	PSB + *Rhizobium*	0.41	0.42	0.20	0.21
4.	Sem ±	0.008	0.008	0.004	0.003
	C.D. (P=0.05)	0.022	0.022	0.010	0.010
b.	**Phosphorus levels (kg ha^{-1})**				
1.	20	0.38	0.39	0.17	0.18
2.	40	0.40	0.41	0.19	0.20
3.	60	0.42	0.43	0.21	0.22
4.	Control	0.36	0.37	0.15	0.16
	Sem ±	0.009	0.010	0.004	0.004
	C.D. (P=0.05)	0.026	0.027	0.012	0.013

Table 3: Potassium content in grain and straw as affected by phosphorus levels and biofertilizers at successivestage of crop growth

S.N.	Treatments	Potassium content in grain (%)		Potassium content in straw (%)	
		2022-23	2023-24	2022-23	2023-24
a.	**Biofertilizer**				
1.	PSB	1.77	1.79	1.23	1.24
2.	*Rhizobium*	1.83	1.85	1.28	1.29

3.	PSB + *Rhizobium*	1.86	1.88	1.30	1.31
4.	Sem ±	0.033	0.034	0.025	0.022
	C.D. (P=0.05)	0.096	0.098	0.071	0.062
b.	**Phosphorus levels (kg ha^{-1})**				
1.	20	1.82	1.84	1.26	1.27
2.	40	1.86	1.88	1.29	1.30
3.	60	1.88	1.90	1.31	1.32
4.	Control	1.72	1.74	1.22	1.23
	Sem ±	0.038	0.039	0.029	0.025
	C.D. (P=0.05)	0.110	0.113	0.082	0.072

CONCLUSION

In conclusion, it can be stated that application of biofertilizer containing PSB is proved from the above results that, it promotes the better transport mechanism, root growth and subsequently yields and quality of grain. It also helps to ensure overall nutrition needed for the plant growth. This research not only enhances the existing knowledge base in the field but also furnishes practical knowledge for the modern farming system to ensure sustainable agriculture. This research emphasizes the significance of biofertilizer application, and reiterates the need for the use of chemical fertilizers that over time impact the soil fertility and health. But, like any research, this research has limited drawbacks namely, short shelf-life as it is sensitive to higher temperature, slow action as compared to chemical fertilizers, and uncertain long term effects that need rigorous research. These restrictions provide opportunities for future research in order to further validate and build upon the current findings. The results of this research will have important implications for the farmers as well as for the entire agricultural sector and pave the way for further researches.

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