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INFLUENCE OF PHOSPHORUS AND BIOFERTILIZERS ON NUTRIENT CONTENT AND UPTAKE OF FIELD PEA

Drishty Katiyar[1]*, Ravindra Kumar[1], Arushi Yadav [2], S.B. Pandey[1] and Devilal Birla[3]

[1]Department of Soil Science and Agricultural Chemistry, CSAUA & T, Kanpur - 208 002 (U.P.), India.
[2]Department of Soil Conservation and Water Management, CSAUA & T, Kanpur - 208 002 (U.P.), India.
[3]Department of Agronomy, Anand Agricultural University, Anand - 388 110, Gujarat, India.
*Corresponding author E-mail : katiyardrishty@gmail.com

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ABSTRACT

The present investigation was carried out at Students' Instructional Farm of C.S.A.U.A.&T., Kanpur (U.P.) during two consecutive *Rabi* seasons of 2021-22 and 2022-2023. Three level of each phosphorus (0, 60, 90 kg ha^{1}), *Rhizobium* inoculation and PSB with and without were used. There are twelve treatments combination which tested with three replications in factorial randomized block design (FRBD). Field pea variety IPFD 6-3 was grown with the recommended agronomic practices. Interaction of phosphorus and biofertilizers further increased growth characters and yield attributes compared to their respective lower level used. Inoculation of *Rhizobium* and PSB significantly increased growth and yield attributes in comparison to uninoculated treatments. Although, plant population increased due to various treatments but increase was non- significant. Seed, stover and biological yield significantly increased due to use of 90 kg P_2O_5 + with *Rhizobium* + with PSB inoculation N, P and K content in seed 3.29%, 0.69%, 1.07% and in stover 1.10%, 0.40%, 1.24%, respectively were found maximum in the treatment T_{12} ($P_{90}R_1PSB_1$) during second year. The phosphorus and biofertilizers during second year under treatment T_{12} [90 kg P + with *Rhizobium* + with PSB]. Phosphorus and biofertilizers inoculation also improved the available N, P and K in the experimental field after crop harvest.

Key words : PSB inoculation, Biofertilizers, *Rhizobium*, Phosphorus.

Introduction

India relies heavily on leguminous crops, with pulses being pivotal as both the largest producer and consumer globally. Pulses boast nearly three times the high-quality protein content found in grains, offering an affordable solution to protein deficiency, particularly in vegetarian diets. Rich in lysine, an essential amino acid lacking in cereals, pulses complement dietary protein needs effectively. India's significant vegetarian population, pulses constitute a cornerstone of the nation's cuisine, catering to a wide range of dietary preferences. Peas, a popular pulse crop, hold particular importance for impoverished communities. Globally, India accounts for one-third of the total area under pulses and a quarter of global production. Known interchangeably as grain legumes, pulse crops serve multifaceted purposes as food, fodder and feed. While cereals and grains fulfill primary nutritional needs, pulses offer a more comprehensive dietary profile. Legumes, often likened to mini-factories, employ biological nitrogen fixation, enriching soil properties and promoting sustainable farming practices. By harnessing atmospheric nitrogen through symbiotic relationships and taproot systems, pulses not only provide ample protein but also enhance soil fertility and ecological balance. Their contribution to soil health underscores their pivotal role in sustainable agriculture, making them indispensable in mitigating the effects of chemical fertilizers and fostering a self-sustaining agricultural ecosystem.

Residual pulse crops represent a valuable asset for small-scale farmers as they can serve as nutritious fodder for livestock and dairy cattle. With a root system capable of producing between 0.8 to 1.5 tons of organic matter upon harvest, pulses contribute significantly to soil fertility and overall farm sustainability. Fifteen to thirty kilograms of nitrogen may be easily added to a crop of one hectare (Singh, 2001). The expected demand for pulses in the nation is 27.7 mt by 2025 to guarantee self-sufficiency. Multiple agro-ecological, biological, institutional and socio-economic limitations contribute to the poor production of various pulses. Peas fix nitrogen from the air, preserving soil fertility. Peas are healthy because of their fiber content. India grows 15.2 million tonnes of pea on 23 million hectares. It grows in marginal, light-textured soils with low moisture and nutrients. The antioxidant vitamins C and E, mineral, zinc and other nutrients are found in peas all work together to boost the body's natural defenses. The pea is a vital cool-season leguminous vegetable that can withstand cold and is grown all throughout the globe.

Peas are a valuable vegetable because of their high protein content (25 percent), although they can only be grown at higher altitudes in the tropics and during the winter months in the subtropics. It is very important to the agricultural sector in India. India contributes 28% of worldwide output from 37% of farmed land making it a prominent player in the pulses industry. In India, peas are grown over an area of 540 thousand hectares, yielding 54,270,000 metric tons of grain (Anonymous, 2021). Due to its significance in the country's agricultural economy, it has a position of substantial value. Field peas originate in southern Europe and western Asia. It is likely native to Italy, southern Asia and northern India east of the Himalayas. China, India, USA, Egypt, Russia and Ethiopia are major field pea producers. India follows China in production and acreage. Uttar Pradesh grows most field peas in India. Uttar Pradesh produces 60% of India's pea. Uttar Pradesh, Madhya Pradesh and Bihar are also big field pea producers. In winter, peas grow well in Uttar Pradesh, Bihar, Haryana, Himachal Pradesh and Punjab. Dal is made from mature field pea seeds. Forage and green manure are also cultivated. Field peas are drought-resistant and farmed in big quantities. Frost-resistant plants. Round, angular seeds. Flowers are usually colorful. Leaf axils typically pigment. Grayish-green, brown or yellow seeds. However, 70% of India's pea harvest comes from Uttar Pradesh according to F.A.O. statistics (2012), 100 grams of green peas has 339 calories, 5.1 grams of dietary fiber, 5.42 grams of protein, 14.45 grams of carbohydrates, 5.67 grams of sugar, 0.4 grammes of fat, 40 milligrams of vitamin C, folic acid (50.7 mg), iron (1.47mg), 108 milligrams of magnesium, and 217 milligrams of potassium.

Phosphorus is a vital nutrient for plant growth, affecting various aspects of field pea development. Its availability in soil influences root development, flowering and overall yield. Proper phosphorus management can enhance field pea growth. Phosphorus shortage may reduce legume nodule, leaf, biomass and grain growth. Symbiotic nitrogen fixation requires a lot of energy (Schulze *et al*., 2006) and energy-generating metabolism relies on phosphorus (Plaxton, 2004). The fertilization boosts root development, photosynthesis, and hydraulic conductivity. Several molecular and biochemical plant activities need phosphorus, including energy intake, storage and usage (Epstein and Bloom, 2005). At limited external phosphorus supply, nodules have more phosphorus per dry weight than roots and shoots. Nitrogen-fixing plants need more P than direct nitrogen fertilization owing to nodule growth, signal transduction, and P-lipids in the vast number of bacterioids (Graham and Vance, 2000). It catalyses plant biological processes and helps transform solar energy into plant chemicals. These chemicals improve plant health and vigor (Griffith, 2010). Because of symbiotic nitrogen fixation, legumes are heavy phosphorus feeders and less sensitive to nitrogen (Kumar *et al*., 2016). Phosphorus boosts root growth, stem strength, flower and seed production, crop maturity, legume nitrogen fixing capacity, crop quality and disease resistance (Rehan *et al*., 2018). It boosts and sustains grain legume output. Legumes need more P because symbiotic nitrogen fixation uses more energy (Islam *et al*., 2012). Phosphate fertilization maintains an adequate supply of P to plant roots by increasing soil solution and liable P concentration. The plants take up about 10-20 percent of applied phosphorus during grading season, and the rest is rendered unavailable. This indicates the need to periodically measure the fertility status to read the P fertilizer dose based on the modified P status. According to the findings of several studies, increasing the amount of phosphorus in the soil over the minimum required for legumes to achieve optimal growth, seed output, and nodulation also results in an improvement in the legumes overall quality. The total Phosphorus content of Indian soils ranges from 130 to 1310 ppm. On average, the alluvial soils of the United Provinces have a phosphorus content of around 380 ppm. Phosphorus (P) is a nutrient that the pea plant requires in quite large amounts. Phosphorus is essential for the formation of robust seedlings and expansive root systems and is required for their growth. In order to promote healthy nodule formation, one of the most important steps is to stimulate robust root growth. Phosphorus is another component that is essential to the process of nitrogen fixation. Phosphorus treatment, on the other hand, may provide the following benefits onto a pea crop: greater frost tolerance, resistance to disease, better nodulation, nitrogen fixation, and drought tolerance. Legumes need phosphorus in relatively high amounts for nitrogen fixation and growth. Leguminous plants need root nodule bacteria-derived nitrogen. An estimated 50 million tonnes of nitrogen are manufactured industrially each year, compared to an estimated 90 million tonnes fixed by plant processes (Ogutcu *et al.*, 2008). Phosphate solubilizing bacteria (PSB) could convert an inorganic form of phosphorus that is unavailable to plants into the soluble forms HPO_4^{2-} and H_2PO_{4-} through a process that involves the production of organic acid, chelating and ion exchange reactions.

Materials and Methods

Experimental site

The investigation was conducted during the Rabi seasons of 2021-2022 and 2022-2023 at the Student Instructional Farm within the premises of C.S.A. University of Agriculture and Technology, Kanpur, Uttar Pradesh. The field underwent thorough leveling and was irrigated using a tube well. This farm is located within the university's main campus, situated in the northwestern part of Kanpur city and falls under the sub-tropical zone in the Vth agro climatic zone, known as the Central Plain Zone.

Description of variety under investigation

Field pea variety IPFD 6-3 had been developed by field pea breeders of ICAR-IIPR, Kanpur in 2005. This variety was released during 2016, SVRC (U.P.) and recommended area for cultivation is Uttar Pradesh. This variety is round seeded and creamy white seed coat colour with moderately resistant against powdery mildew and tolerant to rust. Growth habitat is dwarf type with early vigour and matures in 115-120 days. Average potential 19-20 q/ha^{-1}.

Application of fertilizer : Nitrogen was evenly applied at a rate of 20 kilograms per hectare using urea, while potash was uniformly applied at a rate of 40 kilograms per hectare using muriate of potash. Phosphorus was applied based on the specific treatment requirements, directly into the furrows, positioned 5 cm below the seeds during the sowing process, utilizing single superphosphate.

Method of *Rhizobium* and PSB inoculation : To achieve the desired outcome, a specific amount of cultures, which amounted to 200 grams of culture for every 10 kilograms of seed, were combined with a 10% sugar solution to create slurry. This slurry was then evenly distributed onto the seeds and manually mixed to ensure a uniform coating. Subsequently, the treated seeds were laid out on a polythene sheet in a shaded area to protect them from direct sunlight. These prepared seeds were promptly sown right after the treatment.

Detail of treatments and design : An experimental investigation was undertaken employing a factorial randomized block design featuring three replications to assess the impact of twelve distinct combinations of nutrient management practices. These combinations encompassed three tiers of phosphorus application (0, 60 and 90 kg ha^{-1}), along with two levels of seed inoculation - one without and the other with *Rhizobium* (designated as 0 and 1) and two levels of seed inoculation - one without and the other with phosphate- solubilizing bacteria (PSB) (also designated as 0 and 1). The treatments were categorized as follows: **A)** Levels of Phosphorus: 0 kg ha^{-1} (P_0), 60 kg ha^{-1} (P_{60}) and 90 kg ha^{-1} (P_{90}); **B)** Levels of *Rhizobium:* Without *Rhizobium* (R_0) and With *Rhizobium* (R_1); **C)** Levels of PSB: Without PSB (PSB_0) and With PSB (PSB_1).

Procedure of plant analysis : The chemical analysis of plants for the nutrient content was done when seed and straw samples were collected from each treatment at harvest to analyse nitrogen, phosphorous and potassium concentration (%) and their uptake (kg ha^{-1}). The plant material was oven dried (70± 50C for 72 hours) and ground separately and then subjected to analysis. Plant analysis for the determination of nutrient content in seed and stover were done with the standard procedures viz., nitrogen concentration in plant (both seed and straw) was determined by micro-kjeldahl's method (Jackson, 1973), phosphorus by vanado-molybdo phosphoric acid yellow colour method (Jackson, 1973), potassium by flame photometer (Jackson, 1973). The uptake of nitrogen, phosphorus, potassium and were done by the following formula

$$\text{Nutrient uptake by seed or stover (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content in seed or stover (\%)} \times \text{Seed or stover yield (kg ha}^{-1}\text{)}}{100}$$

Results and Discussion

Nitrogen content and uptake in seed

Nitrogen levels in field pea seeds experienced a notable increase with phosphorus application, reaching optimal concentrations at 90 kg P_2O_5 ha^{-1}. Beyond this threshold, additional phosphorus led to a decline in nitrogen content. Inoculation with *Rhizobium* and PSB markedly boosted nitrogen levels in seeds across both years, particularly under biofertilizer application. Although interactions between phosphorus and biofertilizers lacked statistical significance in nitrogen content, the combined utilization of phosphorus, *Rhizobium* and PSB yielded superior nitrogen levels in seeds. Nitrogen uptake by field pea seeds exhibited a significant rise with graded phosphorus doses, peaking at 90 kg P_2O_5 ha^{-1}. Further increments beyond this level did not yield substantial increases in uptake. *Rhizobium* and PSB inoculation notably enhanced nitrogen uptake by seeds throughout both years, with maximum uptake observed under biofertilizer application (Togay *et al.*, 2008). Interactions between phosphorus and biofertilizers did not display statistical significance in nitrogen uptake. The phosphorus, *Rhizobium* and PSB together showcased superior nitrogen uptake by seeds. In essence, maintaining a balanced phosphorus application and integrating biofertilizers play pivotal roles in optimizing nitrogen content and uptake in field pea seeds, thereby enhancing crop productivity and nutrient management practices.

Nitrogen content and Uptake in Stover : Nitrogen content in field pea stover significantly increased with the application of different phosphorus levels, reaching optimal levels at 90 kg P_2O_5 ha^{-1}. Excessive phosphorus beyond this dosage resulted in a decrease in nitrogen content. Inoculation with *Rhizobium* and PSB significantly enhanced nitrogen content in stover, with maximum levels observed under biofertilizer application**.** Interactions between phosphorus and biofertilizers showed increases in nitrogen content, with the combined use of phosphorus, *Rhizobium*and PSB demonstrating superior effects. Nitrogen uptake by field pea stover increased significantly with graded phosphorus doses, peaking at 90 kg P_2O_5 ha^{-1}. Further increases beyond this level did not result in significant increases in uptake. *Rhizobium* and PSB inoculation significantly increased nitrogen uptake by stover, with maximum uptake observed under biofertilizer application. Interactions between phosphorus and biofertilizers did not show statistical significance in nitrogen uptake (Bejandi *et al*., 2012). However, the combined use of phosphorus, *Rhizobium* and PSB demonstrated superior nitrogen uptake by stover. Overall, balanced phosphorus application and biofertilizer usage play a crucial role in optimizing nitrogen content and uptake in field pea stover, contributing to improved crop productivity and nutrient management practices.

Table 1 : Effect of phosphorus and biofertilizers on nutrient content (%) in seed of field pea.

Treatment	Nutrient content in Seed (%)								
	Nitrogen (N)			Phosphorus (P)			Potassium (K)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1: $P_0R_0PSB_0$	2.85	3.02	2.94	0.23	0.24	0.24	0.85	0.91	0.88
T_2: $P_0R_0PSB_1$	2.89	3.06	2.98	0.27	0.29	0.28	0.88	0.94	0.91
T_3: $P_0R_1PSB_0$	2.95	3.13	3.04	0.51	0.52	0.52	0.92	0.98	0.95
T_4: $P_0R_1PSB_1$	2.97	3.15	3.06	0.58	0.59	0.59	0.93	1.00	0.97
T_5: $P_{60}R_0PSB_0$	3.02	3.20	3.11	0.61	0.62	0.62	0.97	1.04	1.01
T_6: $P_{60}R_0PSB_1$	3.04	3.22	3.13	0.67	0.68	0.68	0.98	1.05	1.02
T_7:$P_{60}R_1PSB_0$	2.91	3.08	3.00	0.24	0.25	0.25	0.90	0.96	0.93
T_8: $P_{60}R_1PSB_1$	2.92	3.10	3.01	0.30	0.32	0.31	0.91	0.97	0.94
T_9: $P_{90}R_0PSB_0$	2.99	3.17	3.08	0.52	0.53	0.53	0.95	1.02	0.99
T_{10}: $P_{90}R_0PSB_1$	3.01	3.19	3.10	0.59	0.60	0.60	0.96	1.03	1.00
T_{11}: $P_{90}R_1PSB_0$	3.07	3.25	3.16	0.63	0.68	0.66	0.99	1.06	1.03
T_{12}: $P_{90}R_1PSB_1$	3.10	3.29	3.20	0.68	0.69	0.69	1.00	1.07	1.04
S.Em ±	**P:** 0.08 **R:** 0.06 **PSB:** 0.06	**P:** 0.08 **R:** 0.06 **PSB:**0.06	**P:** 0.002 **R:** 0.001 **PSB:**0.001	**P:** 0.004 **R:** 0.003 **PSB:**0.003	**P:** 0.004 **R:** 0.003 **PSB:**0.003	**P:** 0.004 **R:** 0.003 **PSB:**0.003	**P:** 0.02 **R:** 0.02 **PSB:** 0.02	**P:** 0.03 **R:** 0.02 **PSB:** 0.02	**P:** 0.002 **R:** 0.001 **PSB:** 0.001
C.D. at 5 %	**P:** NS **R:** NS **PSB:** NS	**P:** NS **R:** NS **PSB:** NS	**P:** 0.005 **R:** 0.004 **PSB:**0.004	**P:** 0.008 **R:** 0.007 **PSB:**0.007	**P:** 0.009 **R:** 0.007 **PSB:**0.007	**P:** 0.009 **R:** 0.007 **PSB:**0.007	**P:** 0.05 **R:** NS **PSB:** NS	**P:** 0.05 **R:**NS **PSB:**NS	**P:** 0.004 **R:** 0.003 **PSB:** 0.003

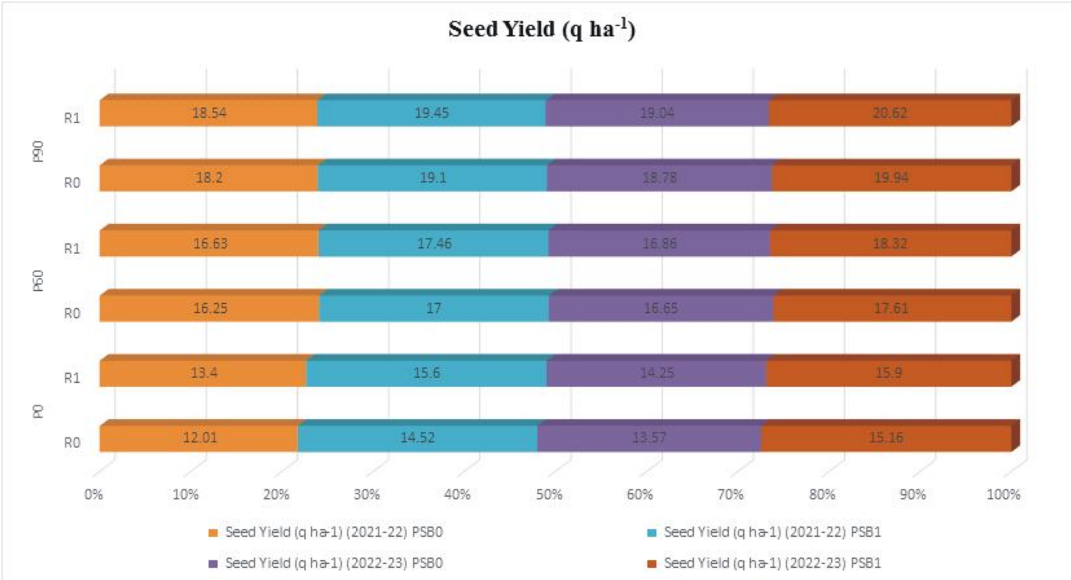

Fig. 1 : This figure provides an overview of seed yield increment within the framework of conducted experiment.

Table 2 : Effect of phosphorus and biofertilizers on nutrient content (%) in stover of field pea.

Treatment	Nutrient Content in Stover (%)								
	Nitrogen (N)			Phosphorus (P)			Potassium (K)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1: $P_0R_0PSB_0$	0.90	0.95	0.93	0.21	0.22	0.22	1.00	1.07	1.04
T_2: $P_0R_0PSB_1$	0.93	0.99	0.96	0.26	0.27	0.27	1.01	1.08	1.05
T_3: $P_0R_1PSB_0$	0.96	1.02	0.99	0.30	0.31	0.31	1.04	1.12	1.08
T_4: $P_0R_1PSB_1$	0.97	1.03	1.00	0.34	0.35	0.35	1.05	1.17	1.11
T_5: $P_{60}R_0PSB_0$	1.00	1.06	1.03	0.36	0.37	0.37	1.13	1.22	1.18
T_6: $P_{60}R_0PSB_1$	1.01	1.07	1.04	0.38	0.39	0.39	1.14	1.24	1.19
T_7:$P_{60}R_1PSB_0$	0.94	1.00	0.97	0.23	0.24	0.24	1.02	1.07	1.05
T_8: $P_{60}R_1PSB_1$	0.95	1.01	0.98	0.27	0.29	0.28	1.03	1.08	1.06
T_9: $P_{90}R_0PSB_0$	0.98	1.04	1.01	0.32	0.33	0.33	1.07	1.12	1.10
T_{10}: $P_{90}R_0PSB_1$	0.99	1.05	1.02	0.35	0.36	0.36	1.11	1.17	1.14
T_{11}: $P_{90}R_1PSB_0$	1.02	1.08	1.05	0.35	0.37	0.36	1.16	1.22	1.19
T_{12}: $P_{90}R_1PSB_1$	1.04	1.10	1.07	0.38	0.40	0.39	1.18	1.24	1.21
S.Em±	**P:** 0.03 **R:** 0.02 **PSB:**0.02	**P:** 0.03 **R:** 0.02 **PSB:** 0.02	**P:**0.001 **R:**0.001 **PSB:**0.001	**P:**0.003 **R:**0.003 **PSB:**0.003	**P:**0.004 **R:** 0.003 **PSB:**0.003	**P:**0.002 **R:**0.001 **PSB:**0.001	**P:**0.03 **R:**0.02 **PSB:**0.02	**P:**0.03 **R:**0.02 **PSB:**0.02	**P:**0.008 **R:**0.006 **PSB:** 0.006
C.D. at 5%	**P:** 0.05 **R:** NS **PSB:** NS	**P:** 0.05 **R:** NS **PSB:** NS	**P:**0.002 **R:**0.002 **PSB:**0.002	**P:**0.007 **R:**0.006 **PSB:**0.006	**P:**0.008 **R:**0.006 **PSB:**0.006	**P:**0.004 **R:**0.003 **PSB:**0.003	**P:**0.06 **R:**NS **PSB:** NS	**P:**0.06 **R:**NS **PSB:**NS	**P:**0.004 **R:**0.003 **PSB:**0.003

Phosphorus content and Uptake in Seed : Phosphorus content in field pea seeds increased significantly with graded phosphorus doses, reaching optimal levels at 90 kg P_2O_5 ha^{-1}. Further increases beyond this level showed a non-significant rise. Inoculation with *Rhizobium* and PSB significantly enhanced phosphorus content in seeds, with maximum levels achieved under biofertilizer application. Interactions between phosphorus and biofertilizers were significant (Abdalla *et al.*, 2011), with the combined use of phosphorus, *Rhizobium* and PSB showing superior effects on phosphorus content in seeds. Phosphorus uptake by

Table 3 : Effect of phosphorus and biofertilizers on nutrient uptake (kg ha^{-1}) by seed of field pea.

Treatment	Nutrient Uptake by Seed (%)								
	Nitrogen (N)			Phosphorus (P)			Potassium (K)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1: $P_0R_0PSB_0$	34.20	41.00	37.60	2.88	3.39	3.14	10.20	12.30	11.25
T_2: $P_0R_0PSB_1$	38.70	43.60	41.15	3.62	4.13	3.88	11.80	13.40	12.60
T_3: $P_0R_1PSB_0$	47.90	52.10	50.00	8.28	8.66	8.47	15.00	16.30	15.65
T_4: $P_0R_1PSB_1$	49.40	53.10	51.25	9.65	9.95	9.80	15.50	16.90	16.20
T_5: $P_{60}R_0PSB_0$	55.00	60.10	57.55	11.10	11.64	11.37	17.70	19.50	18.60
T_6: $P_{60}R_0PSB_1$	56.40	61.30	58.85	12.42	12.95	12.69	18.20	20.00	19.10
T_7: $P_{60}R_1PSB_0$	42.30	46.70	44.50	3.34	3.64	3.49	13.10	14.60	13.85
T_8: $P_{60}R_1PSB_1$	45.60	49.30	47.45	4.52	5.09	4.81	14.20	15.40	14.80
T_9: $P_{90}R_0PSB_0$	50.80	55.80	53.30	8.84	9.33	9.09	16.20	18.00	17.10
T_{10}: $P_{90}R_0PSB_1$	52.60	58.40	55.50	10.30	10.99	10.65	16.80	18.90	17.85
T_{11}: $P_{90}R_1PSB_0$	58.60	64.80	61.70	12.03	13.56	12.80	18.90	21.10	20.00
T_{12}: $P_{90}R_1PSB_1$	60.30	67.80	64.05	13.22	14.23	13.73	19.50	22.10	20.80
S.Em ±	**P:**1.29 **R:**1.06 **PSB:**1.06	**P:**1.42 **R:**1.16 **PSB:**1.16	**P:** **R:** **PSB:**	**P:**0.151 **R:**0.123 **PSB:**0.123	**P:**0.141 **R:**0.115 **PSB:**0.115	**P:**0.122 **R:**0.099 **PSB:**0.099	**P:**0.41 **R:**0.34 **PSB:**0.34	**P:**0.46 **R:**0.37 **PSB:**0.37	**P:**0.15 **R:**0.12 **PSB:**0.12
C.D. at 5%	**P:**2.68 **R:**2.19 **PSB:**2.19	**P:**2.95 **R:**2.41 **PSB:**2.41	**P:**0.93 **R:**0.76 **PSB:**0.76	**P:**0.312 **R:**0.255 **PSB:**0.255	**P:**0.293 **R:**0.239 **PSB:**0.239	**P:**0.268 **R:**0.218 **PSB:**0.218	**P:**0.86 **R:**0.70 **PSB:**0.70	**P:**0.95 **R:**0.78 **PSB:**0.78	**P:**0.32 **R:**0.26 **PSB:** 0.26

field pea seeds increased significantly with graded phosphorus doses, peaking at 90 kg P_2O_5 ha^{-1}. Further increases beyond this level did not reach statistical significance. *Rhizobium* and PSB inoculation significantly increased phosphorus uptake by seeds with the highest uptake observed under biofertilizer application. Interactions between phosphorus and biofertilizers did not show statistical significance in phosphorus uptake. However, the combined use of phosphorus, *Rhizobium* and PSB demonstrated superior phosphorus uptake by seeds. Overall, balanced phosphorus application and biofertilizer usage play a vital role in optimizing phosphorus content and uptake in field pea seeds, contributing to improved crop productivity and nutrient management practices

Phosphorus content and Uptake in Stover : The phosphorus content in field pea stover increased significantly with graded levels of phosphorus application. Optimal levels were observed at 90 kg P_2O_5 ha^{-1}, with further increases beyond this dosage showing a non-significant rise. Inoculation with *Rhizobium* and PSB positively influenced phosphorus content in stover, with maximum levels achieved under biofertilizer application. Interactions between phosphorus and biofertilizers showed significant increases in phosphorus content, with the combined use of phosphorus, *Rhizobium* and PSB being superior (Rana *et al*., 2015). Phosphorus uptake by field pea stover increased significantly with graded phosphorus doses, reaching maximum uptake at 90 kg P_2O_5 ha^{-1}. However, further increases beyond this level did not reach statistical significance. *Rhizobium* and PSB inoculation significantly increased phosphorus uptake by stover, with the highest uptake observed under biofertilizer application. Interactions between phosphorus and biofertilizers showed increased phosphorus uptake, although not statistically significant. The combined use of phosphorus, *Rhizobium* and PSB demonstrated superior phosphorus uptake (Verma and Singh, 2008 and Katiyar *et al*., 2023).

Potassium content and Uptake in Seed : The potassium content and uptake in field pea seeds exhibited variations over the years 2021-22 and 2022-23, with notable impacts observed from phosphorus application, biofertilizers and their interactions.Phosphorus application demonstrated a significant increase in potassium content in seeds with optimal levels noted at 90 kg P_2O_5 ha^{-1}. However, excessive phosphorus beyond this dosage led to decreased potassium content in seeds. Inoculation with

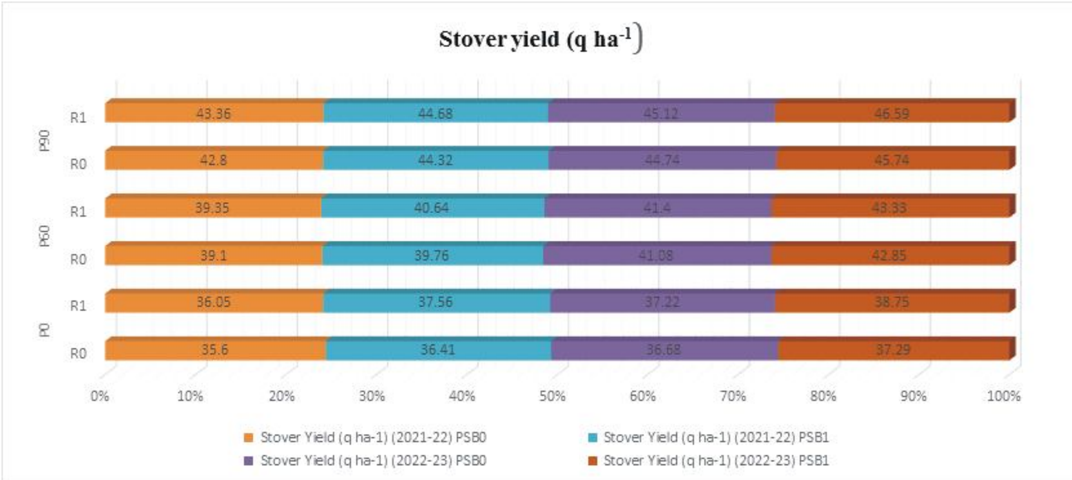

Fig. 2 : This figure provides an overview of stover yield increment within the framework of conducted experiment.

Table4 : Effect of phosphorus and biofertilizers on nutrient uptake (kg ha^{-1}) by stover of field pea.

Treatment	Nutrient Uptake by Stover (%)								
	Nitrogen (N)			Phosphorus (P)			Potassium (K)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1: $P_0R_0PSB_0$	32.00	34.80	33.40	7.48	8.07	7.78	35.60	38.50	37.05
T_2: $P_0R_0PSB_1$	33.50	36.80	35.15	9.37	10.05	9.71	36.40	41.90	39.15
T_3: $P_0R_1PSB_0$	37.50	41.90	39.70	11.73	12.74	12.24	40.70	48.00	44.35
T_4: $P_0R_1PSB_1$	38.20	42.60	40.40	13.37	14.48	13.93	41.30	50.70	46.00
T_5: $P_{60}R_0PSB_0$	42.80	47.40	45.10	15.41	16.55	15.98	48.40	55.80	52.10
T_6: $P_{60}R_0PSB_1$	43.80	48.30	46.05	16.48	17.59	17.04	49.40	57.80	53.60
T_7:$P_{60}R_1PSB_0$	34.20	37.30	35.75	8.37	8.95	8.66	37.10	39.90	38.50
T_8: $P_{60}R_1PSB_1$	35.70	39.10	37.40	10.41	11.24	10.83	38.70	41.90	40.30
T_9: $P_{90}R_0PSB_0$	39.00	44.60	41.80	12.72	14.14	13.43	42.50	48.00	45.25
T_{10}: $P_{90}R_0PSB_1$	40.20	45.50	42.85	14.22	14.87	14.55	45.10	50.70	47.90
T_{11}: $P_{90}R_1PSB_0$	45.20	49.40	47.30	15.51	16.92	16.22	51.40	55.80	53.60
T_{12}: $P_{90}R_1PSB_1$	46.50	51.20	48.85	16.98	18.63	17.81	52.70	57.80	55.25
S.Em ±	**P:**1.01 **R:**0.83 **PSB:** 0.83	**P:**1.12 **R:**0.91 **PSB:**0.91	**P:**0.31 **R:**0.25 **PSB:**0.25	**P:**0.156 **R:**0.128 **PSB:**0.128	**P:**0.200 **R:**0.163 **PSB:**0.163	**P:**0.127 **R:**0.103 **PSB:**0.103	**P:**1.13 **R:**0.92 **PSB:**0.92	**P:**1.24 **R:**1.01 **PSB:**1.01	**P:**0.76 **R:**0.62 **PSB:**0.62
C.D. at 5%	**P:**2.10 **R:**1.71 **PSB:**1.71	**P:**2.32 **R:**1.90 **PSB:**1.90	**P:**0.68 **R:**0.55 **PSB:**0.55	**P:**0.324 **R:**0.265 **PSB:**0.265	**P:**0.414 **R:**0.338 **PSB:**0.338	**P:**0.268 **R:**0.219 **PSB:**0.219	**P:**2.34 **R:**1.91 **PSB:**1.91	**P:**2.57 **R:**2.10 **PSB:** 2.10	**P:**0.78 **R:**0.64 **PSB:** 0.64

Rhizobium and PSB significantly enhanced potassium content in seeds compared to non-inoculated conditions (Singh *et al.*, 2022). Maximum potassium levels were observed with biofertilizer inoculation. Although combined applications of phosphorus and biofertilizers showed increased potassium content in seeds, none of the interactions reached statistical significance. However, the combined use of phosphorus, *Rhizobium* and PSB resulted in superior potassium content in seeds. Phosphorus application also increased potassium uptake by seeds, with the highest uptake observed at 90 kg P_2O_5 ha^{-1} (E-Sheikh *et al.*, 2001). Similar to potassium content, excessive phosphorus doses resulted in decreased potassium uptake. *Rhizobium* and PSB inoculation significantly enhanced potassium uptake by seeds with maximum uptake observed under biofertilizer application. Interactions between phosphorus and biofertilizers showed increased potassium uptake, although not statistically significant. The combined use of phosphorus, *Rhizobium* and PSB demonstrated superior potassium uptake by seeds. Overall, these findings highlight the importance of balanced phosphorus application and biofertilizer usage in optimizing potassium content and uptake in field pea seeds, thus contributing to improved crop yield and nutrient management practices.

Potassium content and Uptake in stover : Application of phosphorus significantly increased potassium content in field pea stover, with the highest levels observed at 90 kg P_2O_5 ha^{-1}. Beyond this level, further phosphorus addition led to a decrease in potassium content. Inoculation with *Rhizobium* and PSB increased potassium content in stover during both years with maximum levels observed under biofertilizer application. Interactions between phosphorus and biofertilizers did not show statistical significance in potassium content, but combined use of phosphorus, *Rhizobium* and PSB resulted in superior potassium content in stover. Potassium uptake by field pea stover significantly increased with graded phosphorus doses, reaching peak levels at 90 kg P_2O_5 ha^{-1} (Gangwar *et al*., 2013). Further increases beyond this level did not result in significant increases in uptake. *Rhizobium* and PSB inoculation significantly increased potassium uptake by stover during both years, with maximum uptake observed under biofertilizer application. Interactions between phosphorus and biofertilizers did not show statistical significance in potassium uptake. However, combined use of phosphorus, *Rhizobium* and PSB demonstrated superior potassium uptake by stover (Singh *et al*., 2018).

Seed and stover yield : Application of phosphorus and biofertilizers significantly influenced the seed and straw yield of field pea during both the years. It is evident from the data shown through graphical representation in Figs. 1 and 2 that illustrates the maximum seed and stover yield was observed with application of [90 kg P + with *Rhizobium* + with PSB] (T_{12}) gave the highest seed yield (20.04q ha^{-1}) and stover yield (45.64 q ha^{-1}), which was statistically at par with [90 kg P + with *Rhizobium* + without PSB] (T_{11}), but significantly higher than rest of the treatments. The increase in seed and straw yield due to adequate supply of available nutrients and synergistic effect of applying different levels of phosphorus and biofertilizers to crop resulting in better growth and development eventually reflected into better seed and stover yields. The increase in yields with biofertilizers was mainly due to the increase in almost all growth and yield contributing characters, which eventually lead to a significant increase in seed and straw yields. These results also confirm with findings of Nagar and Meena (2004), Gupta (2006), Jitendra Kumar (2011), Kumar *et al*. (2016).

Conclusion

In conclusion, the study revealed that increasing doses of phosphorus up to 90 kg ha^{-1} led to significant attributed to phosphorus being an essential nutrient for plants, crucial in various physiological processes. The notable increase in yield due to phosphorus application suggests an improvement in the efficiency of available phosphorus in the experimental field, especially since initial phosphorus levels were below critical limits. These enhancements in growth attributes likely stemmed from improved photosynthetic activity, ultimately contributing in field pea crop.

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