Effect of Phosphorus Solubilizing Bacteria with different levels of phosphorus in field pea *(Pisum sativum)*

Abstract

In the Rabi season of 2022, a comprehensive agricultural experiment was conducted at the Instructional Farm of the Department of Agronomy, located within the Faculty of Agriculture at SAGE University in Bhopal, Madhya Pradesh. The primary objective of this experiment was to assess the influence of varying levels of phosphorus, in conjunction with the application of Phosphorus Solubilizing Bacteria (PSB), on the growth and yield parameters of field pea. This research was undertaken using a randomized block design, with a factorial arrangement that was replicated three times to ensure the reliability and robustness of the findings.

The experiment encompassed seven distinct treatment combinations, which spanned the spectrum from a control group to different percentages of the recommended dose of phosphorus (RDF), including 100%, 80%, 60%, 40%, and 20% of the RDF. The results obtained from this meticulous study unveiled significant impacts of phosphorus levels and the application of Phosphorus Solubilizing Bacteria on several critical growth and yield parameters of field pea. The effects of these factors were observed at multiple stages of the plant's growth, particularly at 30, 60, and 90 days after sowing (DAS). The treatment combination that included 30:60:30 kg per hectare of phosphorus and 200 g per hectare of PSB exhibited outstanding results, with the maximum plant height at 30, 60, and 90 DAS, registering measurements of 39.29 cm and 59.29 cm, respectively.

Remarkably, this specific treatment regimen also led to the highest number of branches per plant at both 60 and 90 DAS, with impressive counts of 7.80 and 9.20 branches, respectively. Furthermore, the combined impact of phosphorus and Phosphorus Solubilizing Bacteria had a profound influence on key yield parameters. Notably, the treatment featuring the combination of 30:60:30 kg per hectare of phosphorus and 200 g per hectare of PSB resulted in the highest values for critical yield parameters, such as the number of pods per plant (17.59), seed yield per hectare (1070 kg), and straw yield per hectare (2142 kg). These findings underscore the pivotal role of this specific treatment regimen in enhancing crop productivity and maximizing overall yield. The results of this experiment offer valuable insights into optimizing phosphorus management practices in the cultivation of field pea, ultimately contributing to improved agricultural sustainability and food security in the region. This research serves as an important contribution to the field of agronomy and provides practical guidance for farmers and researchers alike.

Keywords: Field pea, PSB, plant, grains/pod, grain weight, Stover yield

Introduction

Pea (Pisum sativum L.) stands as a widely favored leguminous vegetable crop cultivated during the cool seasons worldwide. In India, peas are typically grown as a winter vegetable in the northern plains, while in hilly regions, they find a place as an off-season crop, suitable for both summer and winter cultivation. The prominent states for pea cultivation in India include Madhya Pradesh, Uttar Pradesh, Bihar, Haryana, Punjab, and Maharashtra. Nationally, the pea crop spans an area of 554 thousand hectares, resulting in a substantial production of 5524 thousand metric tons, with an impressive productivity rate of 9.971 thousand metric tons per hectare, as reported by the NHB in 2018-19.Delving into the specific case of Madhya Pradesh, the region dedicates 94.99 thousand hectares to pea cultivation, yielding a remarkable 961.55 thousand metric tons.

A multitude of factors play a pivotal role in influencing the crop's yield capacity. Among these factors, phosphorus deficiency takes a prominent position as the most significant single factor contributing to poor nodulation and reduced yields in leguminous crops across diverse soil types. Other influential factors encompass seed attributes, such as size and variety, the shape of pea varieties, sugar content, the choice of growing season, and prevailing temperature conditions.Addressing the crucial issue of phosphorus deficiency, the pea crop's phosphorus requirements can be met through the application of phosphorus fertilizers or the use of Phosphate Solubilizing Bacteria (PSB) as a biofertilizer. These strategies are pivotal in bolstering pea crop yields and overall agricultural productivity.

Phosphorus assumes a pivotal role in fostering the growth and development of crops, directly influencing crucial aspects such as root proliferation, straw durability, grain formation, crop maturation, and overall crop quality. Meeting the requirements of phosphorus, essential for root development and nodulation, predominantly involves the application of inorganic fertilizers. The augmentation of phosphorus availability to crops through the utilization of phosphate solubilizing bacteria (PSB) emerges as a promising approach, especially in the current landscape marked by soaring prices of phosphatic fertilizers in the country and a prevailing deficiency of phosphorus in Indian soils, as documented by Alagawadi and Gaur in 1988.

Bio-fertilizers are renowned for their significant contribution to enhancing the accessibility of both nitrogen and phosphorus, further improving the biological fixation of atmospheric nitrogen and increasing phosphorus availability to crops. Consequently, the introduction of efficient strains of Rhizobium into nitrogen-deficient soils holds the potential to bolster production and promote greater nitrogen fixation, a point emphasized by Gill et al. in 1987. Additionally, it has been noted that aerobic and heterotrophic phosphate solubilizing bacteria play a vital role in facilitating the enhanced availability of phosphorus to pea crops, further underscoring the importance of these beneficial microorganisms in agriculture.

The presence of Phosphate Solubilizing Bacteria (PSB) in nitrogen-deficient soil can play a pivotal role in amplifying agricultural production and, as a result, promoting greater nitrogen fixation. In the context of field pea crops, PSB notably contributes to the liberation of insoluble inorganic phosphate, rendering it accessible to plants. PSB constitute a valuable group of bacteria renowned for their ability to hydrolyze both organic and inorganic phosphorus from otherwise insoluble compounds. This talent in phosphorus solubilization stands as a fundamental trait closely associated with enhancing plant phosphate nutrition.

Employing phosphate solubilizing bacteria as inoculants delivers a dual benefit, simultaneously increasing the plant's uptake of phosphorus and boosting overall crop yields. It's important to note that this enhancement in phosphorus utilization can be further maximized through co-inoculation with other beneficial bacteria and mycorrhiza, highlighting the potential for synergistic benefits from multiple microbial agents in agricultural systems.

Material and method

The experimental design employed in this study adhered to a factorial randomized block layout, with each of the 7 treatments replicated three times. The plot dimensions were standardized at 3 meters by 2 meters, with a 0.50-meter gap between plots and a 1.0-meter separation between replications. The spacing between rows was maintained at 30 centimeters, while the spacing between individual plants within a row was set at 10 centimeters. The recommended seed rate ranged from 80 to 100 kilograms per hectare.

For the pea crop, the recommended fertilizer dosage was 25:60:60 (N: P: K) kilograms per hectare. The specific pea variety used in the experiment was Prakash (IPFD 1-10). Five distinct phosphorus levels, measured in kilograms per hectare (100, 80, 60, 40, and 20), were All standard agronomical practices were meticulously carried out, adhering to the recommended pea cultivation guidelines, from initial field preparation through to the final crop harvesting stages. Throughout the course of the experiment, data were diligently recorded for various parameters, including plant height (in centimeters) at 30, 60, and 90 days after planting, leaf area per plant (in square decimeters), fresh plant weight (in grams), dry plant weight (in grams), days to reach 50% flowering, number of pods per plant, number of seeds per pod, seed weight per plant (in grams), and seed yield per hectare.

The collected data pertaining to growth and yield attributes were subjected to thorough statistical analysis for comprehensive evaluation.

Incorporated into the study, along with a control group featuring 0 levels of phosphorus. Phosphate Solubilizing Bacteria (PSB) were uniformly applied in conjunction with all the treatments prior to crop sowing.

Plant height (cm)

In each plot, a random selection of five plants was made, and these plants were permanently tagged for further measurements. Upon harvest, the height of each tagged plant was measured from the ground to the tip of the plant using a meter scale. The mean plant height was then computed as the average of these measurements obtained from the five tagged plants.

Number of nodules per plant

At 30 days after sowing (DAS), the total and effective number of nodules per plant were meticulously assessed. In each plot, a random selection of five plants was made from sample rows, and these plants were gently uprooted. The soil adhering to the root mass was carefully washed away with water, allowing for the counting of the total number of nodules, which contributed to the determination of the average number of nodules per plant.

The assessment of the effective number of nodules was also conducted using the same plants selected for the total nodule count. Healthy, pink-colored nodules were singled out and counted, with the recorded mean value representing the effective number of nodules per plant.

Yield attributes and yields

Days to flower initiation

The period taken from seeding to the onset of floral bud formation was defined as "days to flower initiation.

Number of pickings

Harvesting was conducted between 80 and 115 days after sowing within the designated net plot. For each picking within the plot, the harvested material was labeled and weighed.

Number of pods per plan plant

The plants selected at random were employed to count the number of pods per plant, and subsequently, the average was calculated.

Number of seeds per pod

At the time of picking, ten pods were randomly selected from each plot and total seeds were counted to record the average number of seeds per pod.

Pod length (cm)

The average of ten randomly selected pods was calculated as a pod length from each plot.

Fresh pod weight (g)At the time of picking of pods, ten pods were randomly selected from each plot and average weight of pod was calculated.

Harvest index (%)

The harvest index serves as a measure of the crop's efficiency in yielding grain output concerning the total biological yield. It was calculated across various treatments using the formula established by Donald in 1962. The calculation involves determining the ratio of the economic yield to the biological yield from the same area, expressed as a percentage.

$$\text{Harvest Index (\%)} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

Economic yield = Seed yield (kg ha^{-1})

Biological yield = seed yield + stover yield (kg ha^{-1})

Green pod yield kg per plot

At each picking, the pod yield of each plot was weighted separately.

Green pod yield q per hectare

At each picking, the pod yield of each plot was weighted separately and converted in terms of q ha-1.

Soil analysis

To evaluate the soil's fertility status, soil samples were collected from each experimental plot after the pea crop was harvested. These samples, taken from a depth of 0 to 15 cm, were air-dried and subsequently passed through a 2 mm sieve. The collected soil samples were then subjected to analysis for parameters including organic carbon, available nitrogen, and phosphorus, with the specific analytical methods outlined in the table.

Economics of the treatment

Cost of cultivation (Rs ha^{-1})

The total expenditure incurred in cultivating the crop within a specific treatment represents the comprehensive cost of agricultural operations. By computing the costs associated with materials, cultivation fees, labor, and various other expenses, the cost of cultivation for each treatment was determined, expressed in Rupees per hectare (Rs ha-1).

Gross return (Rs ha^{-1})

Gross returns, determined by local market pricing, represent the total monetary value of the economic products and byproducts obtained from the crop cultivated across the different treatments.

Net return (Rs ha^{-1})

Net return is obtained by subtracting cultivation costs from gross returns. It is good indicator of suitability of a treatment since it represents the actual income.

Net profit (Rs ha^{-1}) = Gross income (Rs ha^{-1}) - Cost of cultivation (Rs ha^{-1})

Benefit: Cost ratio

Benefit: Cost ratio of each treatment was calculated with the help of the following formula:

Gross return (Rs ha-1)

Benefit cost ratio = Cost of cultivation (Rs ha-1)

Results and Discussion

The data collected for growth parameters, as presented in Table-1, unveiled significant variations driven by both the choice of variety and the levels of phosphorus across various growth stages, specifically at 30, 60, and 90 days after sowing (DAS). Notably, the variety

Prakash (IPFD 1-10) displayed the highest plant height (55.15, 74.24, and 82.23 cm) and branches per plant (1.07, 2.54, and 3.17) at 30, 60, and 90 DAS, respectively.

The application of phosphorus also exerted a substantial influence on these growth parameters. The maximum plant height (cm) at 30, 60, and 90 DAS (41.2, 47.7, and 53.6 cm) and dry matter accumulation at 30, 60, and 90 DAS (24.5, 30.2, and 38.2 g per plant) was observed in the treatment with 40 kg P2O5 per hectare, followed closely by the 30 kg P2O5 per hectare treatment. Conversely, the minimum plant height and branches per plant were recorded in the treatments with no phosphorus (0 kg P2O5 per hectare) at 30, 60, and 90 DAS, respectively.

Table 1 Effect of Phosphorus and PSB application on growth, yield and quality of field pea (Pisum sativum L.)

Treatments	Plant Height (cm)	Dry matter Accumulation (g/plant)	Branches/plant	Pods/plant	Seed/pods	Test weight (g)
		Phosphorus and PSB Levels				
Absolute control	55.15	11.12	1.07	8.15	4.14	165.39
Recommended dose of fertilizer (100%) without PSB	74.24	19.45	2.54	15.12	6.79	192.52
Recommended dose of fertilizer (100%) + PSB	82.23	20.6	3.17	17.59	5.25	183.42
Recommended dose of fertilizer (80%) + PSB	77.15	18.6	2.14	14.65	5.15	175.41
Recommended dose of fertilizer (60%) + PSB	72.34	15.9	1.15	13.43	6.27	179.55
Recommended dose of fertilizer (40%) + PSB	68.12	14.13	1.35	12.14	4.18	168.66
Recommended dose of fertilizer (20%) + PSB	70.43	12.17	2.23	11.31	3.15	158.74
Sem	1.66	0.39	0.08	0.41	0.19	4.76
CD	4.85	1.42	0.25	0.85	0.65	0.58

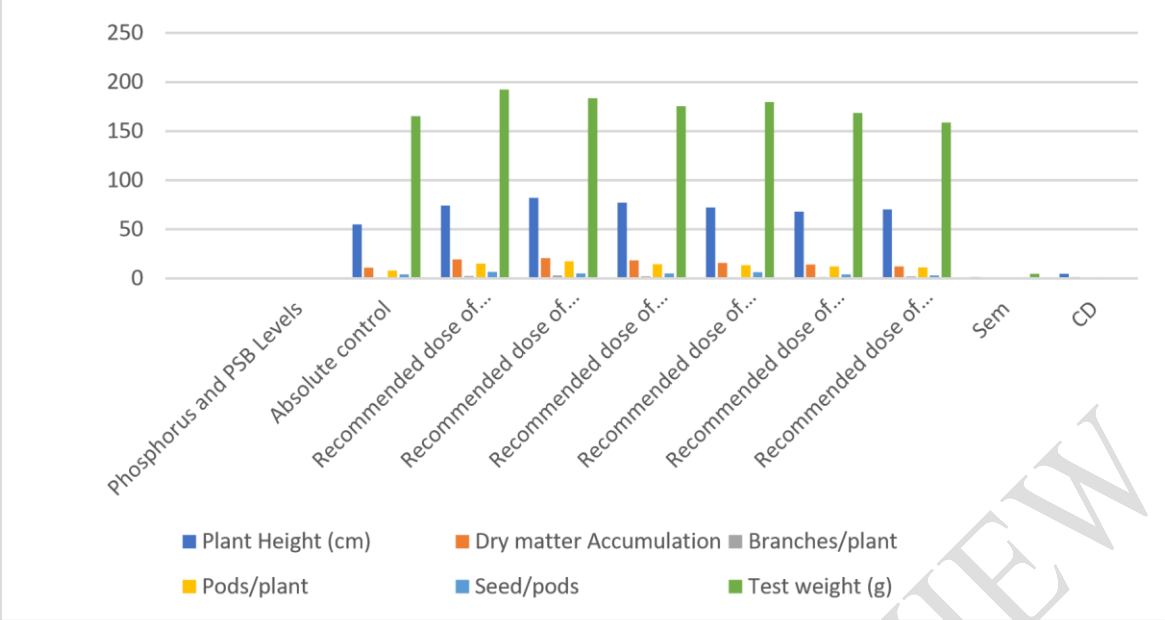

Fig 1. Graphical presentation showing P and PSB levels

The positive impact of phosphorus application on root elongation appears to have stimulated overall plant growth, as evidenced by the observed increases in plant height and fresh plant weight. Additionally, phosphorus application had a favorable effect on root nodulation, contributing to the development of an extensive and robust root system in seedlings. This, in turn, is a crucial step in promoting nodule formation.

The influence of different varieties and phosphorus levels on various parameters, including the number of pods per plant, the number of seeds per pod, seed weight per plant, and seed yield (in quintals per hectare), was significantly noted. These findings align with previous reports in the literature. Regarding phosphorus levels, the highest number of pods per plant (31.7) was observed in the treatment with 40 kg P2O5 per hectare, closely followed by the 30 kg P2O5 per hectare treatment. Conversely, the lowest number of pods per plant (23.5) was recorded in the absence of phosphorus (0 kg P2O5 per hectare).

Notably, leguminous crops like peas exhibit a heightened demand for phosphorus compared to other crops due to their extensive root development and intensive metabolic activities. Phosphorus is a vital component involved in various critical processes, including its role in DNA, RNA, ATP, and the photosynthetic system, as well as its involvement in catalyzing numerous biochemical reactions that span from the early stages of seedling growth to grain formation at maturity.

Table.2 Effect of Phosphorus Solubilising Bacteria with different levels of phosphorus on Seed, straw, biological yield and harvest index.

Treatments	Seed yield (kg/ha.)	Straw yield (kg/ha.)	Biological yield (kg/ha.)	Harvest index (%)	Net return (Rs/ha)	B:C ratio
P and PSB Levels						

Absolute control	240	545	1007	35.07	825	0.56
Recommended dose of fertilizer (100%) without PSB	1070	2142	4245	31.16	1637	1.13
Recommended dose of fertilizer (100%) + PSB	845	1647	32/56	32.10	1475	1.07
Recommended dose of fertilizer (80%) + PSB	715	1342	2674	31.54	1335	1.02
Recommended dose of fertilizer (60%) + PSB	589	958	1858	31.17	1222	1.01
Recommended dose of fertilizer (40%) + PSB	480	748	1458	30.58	1146	0.98
Recommended dose of fertilizer (20%) + PSB	398	685	1345	28.45	975	0.79
SEM	20.4	42.49	85.8	0.43	175.32	0.04
CD	75.2	123.58	285.4	0.79	489.07	0.08

Conclusion:

In conclusion, the data collected from the experiment conducted with different varieties of field pea and varying levels of phosphorus revealed significant impacts on growth and yield parameters across different growth stages. Notably, the variety "Prakash" demonstrated remarkable performance in terms of plant height and branches per plant at 30, 60, and 90 days after sowing (DAS), indicating its suitability for cultivation in the given conditions.

The application of phosphorus had a substantial influence on various growth parameters, with the treatment featuring 40 kg P2O5 per hectare showing the highest plant height and dry matter accumulation at different growth stages. This highlights the importance of phosphorus as a crucial nutrient for stimulating root elongation and overall plant growth. Additionally, the positive effect of phosphorus on root nodulation underscores its role in promoting nodule formation, which is vital for nitrogen fixation in leguminous crops like field peas.Furthermore, the impact of different varieties and phosphorus levels on key yield parameters, such as the number of pods per plant, seeds per pod, seed weight per plant, and seed yield, was evident. These findings align with existing literature, emphasizing the importance of phosphorus in enhancing yield and crop productivity. The observation that leguminous crops like peas have a higher demand for phosphorus due to their extensive root development and metabolic activities underscores the critical role of phosphorus in various biochemical processes, from seedling growth to grain formation.Overall, this research provides valuable insights into optimizing the cultivation of field pea by considering both the choice of variety and the appropriate application of phosphorus. These findings contribute to our understanding of how to maximize crop yield and agricultural sustainability, ultimately benefiting farmers and researchers seeking to enhance crop production in similar agro-ecological contexts.

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