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# EFFECT OF PHOSPHOROUS AND PHOSPHOROUS SOLUBILIZING BACTERIA (PSB) ON GROWTH, YIELD AND YIELD ATTRIBUTES OF SOYBEAN

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**ABSTRACT**

A pot experiment was conducted during *kharif,* 2022 at the Department of Soil Science & Agricultural Chemistry, College of Agriculture, Junagadh Agricultural University, Junagadh to study the effect of Phosphorus and Phosphorus Solubilizing Bacteria (PSB) on soil phosphorus availability, yield and nutrient uptake by soybean. The experiment was laid out in a factorial completely randomized design with three replications, comprising 16 treatment combinations of four phosphorus levels (0, 40, 60, 80 kg ha$^{-1}$) and four PSB levels (0, 1, 2, 3 l ha$^{-1}$). Results revealed that the application of 80 kg $P_2O_5$ ha$^{-1}$ significantly increased plant height, number of branches, number of nodules, number of pods, number of seeds pod$^{-1}$, seed yield (6.75 g plant$^{-1}$), stover yield (15.56 g plant$^{-1}$), and 100 seed weight. However, phosphorus & PSB application did not exert any significant effect on the protein content in seed.

***Key words :*** Growth parameters, Yield, Yield attributes, Soybean, Phosphorus, PSB.

## Introduction

In the world, India is the largest producer of pulses. Soybean [*Glycine max* (L.) Merrill], a leguminous crop, originated in China. It is basically a pulse crop and has gained importance as an oilseed crop because it contains 20% cholesterol-free oil. It is an introduced and commercially exploited crop in India. In India, the area, production, and productivity of soybean during the year 2021 was 12.04 million hectares, 14.97 million tonnes, and 976.2 kg ha$^{-1}$, respectively (Anonymous, 2022). Maharashtra stood first in both area and production. Soybean is considered a miracle crop because of its dual qualities, *viz.*, high protein (40-42%) and oil content (20%) in seed. It also contains various vitamins and minerals. Soybean protein is rich in the valuable amino acid lysine (5%) (Dhadave *et al.*, 2018). Being a legume, it fixes a large amount of atmospheric nitrogen in the soil and improves soil fertility by leaving residual nitrogen (50-300 kg ha$^{-1}$) through the fixation of atmospheric nitrogen. Therefore, soybean improves the soil fertility in which it is grown. It transfers nitrogen taken from the air into the soil, making it rich and fertile. Soybean crop is known as the "Golden Bean," "Miracle Crop," "Wonder Crop" and "gold of soil." It is well known that the common Indian diet is deficient in protein in both quality and quantity. In this respect, soybean could be regarded as "boneless meat," as it is rich in protein. Among grain legumes, soybean is an economically important crop that can be grown in diverse environments throughout the world.

Phosphorus is a major and essential macronutrient required for the growth and development of plants. It is the tenth most abundant element in the earth's crust. It is also called "key of life." It plays a key role in different growth processes occurring in plants, such as root production, flowering, seed formation, photosynthesis, maturation and is essential for energy transfer, other biochemical and genetic activities of the plant. Its functions cannot be performed by any other nutrient, and an adequate supply of P is required for optimum growth and reproduction. Phosphorus can limit normal plant growth if not provided by the soil or by appropriate quantities of fertilizers. Phosphorus is one of the most immobile, inaccessible, and unavailable nutrients present in the soil, so it is considered a most limited factor for many crop production systems, due to the formation of complexes with Al or Fe in acidic soils or Ca in calcareous soils (Nisha *et al*., 2014).

Microbial inoculants are cost-effective, eco-friendly, and renewable sources of plant nutrients. Plant beneficial living microbial cultures (bio-fertilizers) are a safe supplement to chemical fertilizers to minimize ecological disturbance. Biofertilizers are commonly called microbial inoculants. *Rhizobium* and PSB inoculants help to increase the yield of legume crops by fixing atmospheric nitrogen in root nodules and by converting insoluble phosphate into soluble form, respectively (Raja and Takankhar, 2017). Phosphorus solubilizing bacteria (PSB) can play an important role in the solubilization of soil P through the secretion of various organic acids. It also plays an important role in increasing P availability by solubilizing the fixed P and supplying it to plants in a more available form (Khan and Zaidi, 2007). The biochemical properties of soil have often been proposed as early and sensitive indicators of soil ecosystem health. Activities of soil enzymes indicate the direction and strength of all kinds of bioche[1]mical processes in the soil and act as a key biological indicator of soil health. Soil enzymes play an essential role in energy transfer, environmental quality, organic matter decomposition, nutrient cycling, and crop productivity (Mina *et al*., 2011). A number of microorganisms are considered important for agriculture to promote better enzyme activity and the biological health of the soil. Since the information on soybean inoculation with PSB inoculants is meager, this study was undertaken.

## Materials and Methods

A pot experiment was conducted during *kharif*, 2022 in the Net house of the Department of Soil Science & Agricultural Chemistry, College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat. The soil of the experimental site was clay in texture and slightly alkaline in reaction (7.98) with an EC of 0.48 dSm$^{-1}$. The soil was low in available nitrogen (225 kg ha$^{-1}$), medium in available phosphorus (37.49 kg ha$^{-1}$), high in available potash (321.93 kg ha$^{-1}$) and medium in available Sulphur (17.9 ppm).

The experiment was laid out in a factorial completely randomized design with three replications, having 16 treatment combinations *viz*., 4 levels of phosphorus (0, 40, 60, 80 kg ha$^{-1}$) and 4 levels of phosphorus solubilizing bacteria (PSB) (0, 1, 2, 3 l ha$^{-1}$). The various treatments were control ($T_1$ - without application of phosphorus and PSB), without P but PSB 1 l ha$^{-1}$ ($T_2$), without phosphorus but PSB 2 l ha$^{-1}$ ($T_3$), without P but PSB 3 l ha$^{-1}$ ($T_4$), P40 and PSB 0 l ha$^{-1}$ ($T_5$), P40 and PSB 1l ha$^{-1}$ ($T_6$), P40 and PSB 2 l ha$^{-1}$ ($T_7$), P40 and PSB 3 l ha$^{-1}$ ($T_8$), P60 and PSB 0 l ha$^{-1}$ ($T_9$), P60 and PSB 1 l ha$^{-1}$ ($T_{10}$), P60 and PSB 2 l ha$^{-1}$ ($T_{11}$), P60 and PSB 3 l ha$^{-1}$ ($T_{12}$), P80 and PSB 0 l ha$^{-1}$ ($T_{13}$), P80 and PSB 1 l ha$^{-1}$ ($T_{14}$), P80 and PSB 2 l ha$^{-1}$ ($T_{15}$) and P80 and PSB 3 l ha$^{-1}$ ($T_{16}$). The pots were uniformly basal dressed with 30 kg N ha$^{-1}$ in the form of urea and DAP and phosphorus was applied as per the treatments. PSB was applied as per the treatments. The soybean variety GJS-3 was sown in each pot with 5 seeds. The soil samples from each pot were collected at 30, 60 DAS and at harvest.

## Results and Discussion

### Growth Parameters

### Effect of Phosphorus

Application of 80 kg phosphorus significantly increased plant height at 30, 60 DAS and harvest, and also the number of branches plant$^{-1}$ and number of nodules plant$^{-1}$. At all stages, plant height increased up to 80 kg $P_2O_5$ ha$^{-1}$. The application of P may directly influence the availability of soil phosphorus and may also increase the availability of other nutrients, thus balancing the nutrient requirement and resulting in crop growth. A higher number of nodules plant$^{-1}$ was observed with the application of phosphorus in the treatment P3 (80 kg $P_2O_5$ ha$^{-1}$) at 45 DAS. This is because phosphorus enhances nodulation and nitrogen fixation in soybean. It may be interpreted that the relatively higher availability of phosphorus in the rhizosphere might have helped Rhizobium activity, which resulted in a higher number of effective nodules. A significantly higher number of branches plant$^{-1}$ (5.79) was registered under the treatment P3 (80 kg $P_2O_5$ ha$^{-1}$), but it was found to be statistically at par with treatment P2 (60 kg $P_2O_5$ ha$^{-1}$). Phosphorus has been considered an essential constituent of all living organisms and plays an important role in the conservation and transfer of energy in the metabolic reactions of living cells, including biological energy transformations. In terms of significance, phosphorus is a more indispensable mineral nutrient as it helps in better growth and development. Similar results were reported by Devi *et al.* (2012) and Akbari *et al.* (2010), who found that the application of 80 kg $P_2O_5$ significantly increased growth parameters in soybean crop.

### Effect of Phosphorus Solubilizing Bacteria

The application of 3 l ha$^{-1}$ of PSB significantly increased plant height, number of branches plant$^{-1}$, and number of nodules plant$^{-1}$. The increases in these traits

**Table 1 :** Effect of phosphorus and PSB on plant height at 30, 60 DAS and at harvest of the crop.

| Treatments | Plant height (cm) | | |
|---|---|---|---|
| | 30 DAS | 60 DAS | At harvest |
| **Phosphorus (P)** | | | |
| $P_0$ : 0 kg $P_2O_5$ $ha^{-1}$ | 21.24 | 32.44 | 42.56 |
| $P_1$ : 40 kg $P_2O_5$ $ha^{-1}$ | 21.95 | 34.33 | 43.81 |
| $P_2$ : 60 kg $P_2O_5$ $ha^{-1}$ | 22.87 | 38.63 | 45.37 |
| $P_3$ : 80 kg $P_2O_5$ $ha^{-1}$ | 23.73 | 39.73 | 47.09 |
| S.Em. ± | 0.34 | 0.56 | 0.65 |
| C.D. at 5% | 0.98 | 1.60 | 1.88 |
| **Phosphorus Solubilizing Bacteria (PSB)** | | | |
| $PSB_0$ : 0 L PSB $ha^{-1}$ | 21.79 | 34.19 | 43.13 |
| $PSB_1$ : 1 L PSB $ha^{-1}$ | 22.13 | 35.73 | 44.20 |
| $PSB_2$ : 2 L PSB $ha^{-1}$ | 22.69 | 37.10 | 45.11 |
| $PSB_3$ : 3 L PSB $ha^{-1}$ | 23.18 | 38.18 | 46.38 |
| S.Em.± | 0.34 | 0.56 | 0.65 |
| C.D. at 5% | 0.98 | 1.60 | 1.88 |
| **Interaction (P x PSB)** | | | |
| S.Em. ± | 0.68 | 1.11 | 1.31 |
| C.D. at 5% | NS | NS | NS |
| C.V.% | 5.27 | 5.31 | 5.07 |

**Table 2 :** Effect of phosphorus and PSB on number of branches $plant^{-1}$ (at harvest) and number of nodules $plant^{-1}$ (45 DAS) of soybean.

| Treatments | Number of branches $plant^{-1}$ | Number of nodules $plant^{-1}$ |
|---|---|---|
| **Phosphorus (P)** | | |
| $P_0$ : 0 kg $P_2O_5$ $ha^{-1}$ | 4.27 | 2.92 |
| $P_1$ : 40 kg $P_2O_5$ $ha^{-1}$ | 4.62 | 3.83 |
| $P_2$ : 60 kg $P_2O_5$ $ha^{-1}$ | 5.54 | 5.58 |
| $P_3$ : 80 kg $P_2O_5$ $ha^{-1}$ | 5.79 | 6.00 |
| S.Em. ± | 0.10 | 0.19 |
| C.D. at 5% | 0.28 | 0.55 |
| **Phosphorus Solubilizing Bacteria (PSB)** | | |
| $PSB_0$ : 0 L PSB $ha^{-1}$ | 4.59 | 3.42 |
| $PSB_1$ : 1 L PSB $ha^{-1}$ | 4.91 | 4.58 |
| $PSB_2$ : 2 L PSB $ha^{-1}$ | 5.27 | 4.92 |
| $PSB_3$ : 3 L PSB $ha^{-1}$ | 5.45 | 5.42 |
| S.Em. ± | 0.10 | 0.19 |
| C.D. at 5% | 0.28 | 0.55 |
| **Interaction (PxPSB)** | | |
| S.Em. ± | 0.19 | 0.38 |
| C.D. at 5% | NS | NS |
| C.V.% | 6.61 | 14.43 |

by the application of PSB over untreated treatment (control) might be due to the fact that PSB builds up the biological properties of the soil and also increases nutrient availability for a prolonged period due to microbial activities. Furthermore, the availability of phosphorus in the rhizosphere might have helped Rhizobium activity, which resulted in a higher number of effective nodules. Similar results were reported by Devi *et al.* (2012), Mnisha *et al.* (2006) and Singh *et al.* (2010) in soybean and Son *et al.* (2006) in chickpea.

### Interaction effect of Phosphorus and PSB

The interaction effect of different levels of phosphorus and PSB was found to be non-significant at harvest in respect of plant height, number of plants $plant^{-1}$, number of branches $plant^{-1}$ and number of nodules $plant^{-1}$.

### Yield attributes and Yield

### Effect of Phosphorus

Increasing levels of applied phosphorus up to 80 kg $ha^{-1}$ significantly improved the number of pods $plant^{-1}$, number of seeds $plant^{-1}$, 100 seed weight, seed yield, and stover yield over lower doses. The regulatory function of phosphorus in photosynthesis and carbohydrate metabolism of plant leaves can be considered one of the major factors limiting growth, particularly during the reproductive phase. The level of phosphorus supply during this period regulates the starch-sucrose ratio in the leaves and the partitioning of photosynthates between the leaves and reproductive organs. Edwin *et al.* (2018) and Devi *et al.* (2012) reported similar results for yield and yield attributes due to increasing levels of phosphorus in soybean. Turuko and Mohammed (2014) in common beans and Kumar *et al.* (2006) in moth bean also found similar results.

### Effect of Phosphorus Solubilizing Bacteria

The data revealed that the application of 3 l $ha^{-1}$ of PSB (PSB3) had a significant influence on the number of pods $plant^{-1}$, number of seeds $pod^{-1}$, 100 seed weight, seed yield, and stover yield over lower doses. The improvement in yield and yield attributes might be due to the fact that phosphorus tends to increase growth and development in terms of plant height, branches and dry matter by improving the nutritional environment of the rhizosphere and plant system, which leads to improved plant metabolism and photosynthetic activity. Similar

**Table 3 :** Effect of phosphorus and PSB on number of pods plant$^{-1}$, number of seeds pod$^{-1}$ (at harvest) and 100 seed weight (at harvest) on soybean.

| Treatments | No. of pods plant$^{-1}$ | No. of seeds pod$^{-1}$ | 100 seed weight |
|---|---|---|---|
| **Phosphorus (P)** | | | |
| $P_0$ : 0 kg $P_2O_5$ ha$^{-1}$ | 20.42 | 2.71 | 9.08 |
| $P_1$ : 40 kg $P_2O_5$ ha$^{-1}$ | 21.20 | 2.82 | 9.25 |
| $P_2$ : 60 kg $P_2O_5$ ha$^{-1}$ | 21.94 | 2.92 | 9.43 |
| $P_3$ : 80 kg $P_2O_5$ ha$^{-1}$ | 22.83 | 3.03 | 9.75 |
| S.Em.± | 0.33 | 0.05 | 0.14 |
| C.D. at 5% | 0.95 | 0.15 | 0.39 |
| **Phosphorus Solubilizing Bacteria (PSB)** | | | |
| $PSB_0$ : 0 L PSB ha$^{-1}$ | 20.96 | 2.75 | 9.09 |
| $PSB_1$ : 1 L PSB ha$^{-1}$ | 21.19 | 2.82 | 9.29 |
| $PSB_2$ : 2 L PSB ha$^{-1}$ | 22.07 | 2.91 | 9.47 |
| $PSB_3$ : 3 L PSB ha$^{-1}$ | 22.17 | 2.98 | 9.67 |
| S.Em.± | 0.33 | 0.05 | 0.14 |
| C.D. at 5% | 0.95 | 0.15 | 0.39 |
| **Interaction (PxPSB)** | | | |
| S.Em.± | 0.66 | 0.10 | 0.27 |
| C.D. at 5% | NS | NS | NS |
| C.V.% | 5.32 | 6.30 | 5.01 |

results were reported by Sharma *et al.* (2018), Edwin *et al.* (2018) and Shome *et al.* (2022) in soybean crops.

### Interaction effect of Phosphorus and PSB

Interaction effect of different levels of phosphorus and PSB was found to be non-significant for the number of pods plant$^{-1}$, number of seeds plant$^{-1}$, 100 seed weight, seed yield and stover yield.

### Quality Parameters

### Protein Content

The data presented in Table 5 indicated that different phosphorus levels increased protein content. The maximum protein content (30.67%) was observed in $P_3$ (80 kg ha$^{-1}$) but could not show a significant effect on protein content.

### Effect of Phosphorus Solubilizing Bacteria

A perusal of the data in Table 5 indicated that different levels of phosphorus solubilizing bacteria increased protein content but did not show a significant effect on protein content.

**Table 4 :** Effect of phosphorus and PSB on seed yield and stover yield (g plant$^{-1}$) on soybean.

| Treatments | Seed yield (g plant$^{-1}$) | Stover yield (g plant$^{-1}$) |
|---|---|---|
| **Phosphorus (P)** | | |
| $P_0$ : 0 kg $P_2O_5$ ha$^{-1}$ | 5.16 | 13.24 |
| $P_1$ : 40 kg $P_2O_5$ ha$^{-1}$ | 5.50 | 13.92 |
| $P_2$ : 60 kg $P_2O_5$ ha$^{-1}$ | 6.37 | 14.67 |
| $P_3$ : 80 kg $P_2O_5$ ha$^{-1}$ | 6.75 | 15.56 |
| S.Em. ± | 0.13 | 0.28 |
| C.D. at 5% | 0.39 | 0.81 |
| **Phosphorus Solubilizing Bacteria (PSB)** | | |
| $PSB_0$ : 0 L PSB ha$^{-1}$ | 5.18 | 13.55 |
| $PSB_1$ : 1 L PSB ha$^{-1}$ | 5.89 | 14.21 |
| $PSB_2$ : 2 L PSB ha$^{-1}$ | 6.33 | 14.62 |
| $PSB_3$ : 3 L PSB ha$^{-1}$ | 6.37 | 15.02 |
| S.Em. ± | 0.13 | 0.28 |
| C.D. at 5% | 0.39 | 0.81 |
| **Interaction (PxPSB)** | | |
| S.Em.± | 0.27 | 0.56 |
| C.D. at 5% | NS | NS |
| C.V.% | 7.82 | 6.75 |

### Interaction Effect of Phosphorus and PSB

The interaction effect of different levels of phosphorus and PSB on the concentration of protein content was found to be non-significant.

## Conclusion

Based on the findings, the application of both phosphorus and phosphorus-solubilizing bacteria (PSB) significantly improved the growth, yield, and yield attributes of soybean. The highest phosphorus level (80 kg $P_2O_5$ ha$^{-1}$) and PSB application (3 l ha$^{-1}$) were individually most effective, leading to significant increases in plant height, branching, nodulation, and ultimately, a substantial boost in both seed and stover yield.

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