



INFLUENCE OF PHOSPHORUS FERTILIZERS AND PHOSPHOROUS SOLUBILIZING BACTERIA (PSB) INOCULATION ON SOIL NUTRIENT AVAILABILITY IN SOYBEAN

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ABSTRACT

A pot experiment was conducted during *kharif*, 2022 in the Net house of 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 factorial completely randomized design with three replications having 16 treatments 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). Results revealed that availability of nutrients in soil like N, K and S after harvest of soybean unaffected under the application Phosphorus and PSB. Whereas, the soil phosphorus availability at 30, 60 DAS and at harvest were significantly increased by the application of phosphorus up to 80 kg ha⁻¹ and PSB 3 l ha⁻¹.

Key words : Phosphorus, Soybean, Available nutrients and PSB.

Introduction

India is the leading global producer of pulses. Soybean (*Glycine max* L. Merrill), a leguminous crop of Northern Chinese origin, is primarily categorized as a pulse but has also attained importance as an oilseed owing to its 20% cholesterol-free oil content. Following its introduction and commercial adoption in India, soybean cultivation expanded to 12.04 million hectares with a production of 14.97 million tonnes and an average productivity of 976.2 kg ha⁻¹ during 2021 (Anonymous, 2022). Maharashtra ranks first in both acreage and production (FAO). Owing to its dual attributes of high protein (40–42%) and oil content (20%), soybean is regarded as a “miracle crop.” It is rich in essential vitamins, minerals, and amino acids like lysine (5%) (Dhadave *et al.*, 2018). Soybean cultivation in India began in 1977 and has since become an important dietary protein source. As a leguminous crop, it fixes substantial atmospheric nitrogen, contributing 50–300 kg ha⁻¹ of residual nitrogen and enhancing soil fertility for subsequent crops. With its high protein content,

soybean also helps address protein deficiency in the Indian diet. Owing to its nutritional value, soil-enriching ability, and wide adaptability, soybean is recognized as one of the most economically important grain legumes worldwide.

Phosphorus is an essential macronutrient, often referred to as the “key of life,” due to its critical role in plant growth and development. Although it is the tenth most abundant element in the Earth’s crust, its availability to plants is often limited. Phosphorus is indispensable for several physiological and biochemical processes, including root development, flowering, seed formation, photosynthesis, maturation, energy transfer and genetic functions, with no other nutrient able to substitute its role. Deficiency arising from low soil availability or insufficient fertilizer application severely restricts normal plant growth. In soils, phosphorus is among the least mobile and most inaccessible nutrients, as it readily forms insoluble complexes with aluminium and iron in acidic soils and with calcium in calcareous soils. This limited

mobility makes phosphorus one of the major constraints in many crop production systems (Nisha *et al.*, 2014).

Microbial inoculants represent cost-effective, sustainable, and environmentally benign sources of plant nutrition. These biofertilizers, comprising living microbial cultures, are recognized as efficient alternatives to chemical fertilizers, thereby contributing to the reduction of ecological disturbances. Among the most prominent inoculants are *Rhizobium* and phosphorus-solubilizing bacteria (PSB). *Rhizobium* enhances legume productivity through atmospheric nitrogen fixation in root nodules, whereas PSB facilitate phosphorus availability by transforming insoluble forms into plant-accessible soluble phosphates (Raja and Takankhar, 2017). Phosphorus solubilizing bacteria (PSB) play a crucial role in enhancing soil phosphorus availability by secreting organic acids that solubilize fixed phosphorus, making it more accessible to plants (Khan and Zaidi, 2007).

Materials and Methods

A pot experiment was conducted during the kharif season of 2022 in the Net House of the Department of Soil Science & Agricultural Chemistry at the College of Agriculture, Junagadh Agricultural University, Junagadh, Gujarat. The soil at the experimental site was clayey in texture, slightly alkaline in reaction (pH 7.98) and had an electrical conductivity (EC) of 0.48 dSm⁻¹. The soil's nutrient content was characterized as 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 conducted using a factorial completely randomized design with three replications, consisting of 16 treatment combinations. These treatments included 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 treatments were as follows: control (no phosphorus or PSB) (T₁), no phosphorus but with PSB 1 L ha⁻¹ (T₂), no phosphorus but with PSB 2 L ha⁻¹ (T₃), no phosphorus but with PSB 3 L ha⁻¹ (T₄), 40 kg P₂O₅ ha⁻¹ with no PSB (T₅), 40 kg P₂O₅ ha⁻¹ with PSB 1 L ha⁻¹ (T₆), 40 kg P₂O₅ ha⁻¹ with PSB 2 L ha⁻¹ (T₇), 40 kg P₂O₅ ha⁻¹ with PSB 3 L ha⁻¹ (T₈), 60 kg P₂O₅ ha⁻¹ with no PSB (T₉), 60 kg P₂O₅ ha⁻¹ with PSB 1 L ha⁻¹ (T₁₀), 60 kg P₂O₅ ha⁻¹ with PSB 2 L ha⁻¹ (T₁₁), 60 kg P₂O₅ ha⁻¹ with PSB 3 L ha⁻¹ (T₁₂), 80 kg P₂O₅ ha⁻¹ with no PSB (T₁₃), 80 kg P₂O₅ ha⁻¹ with PSB 1 L ha⁻¹ (T₁₄), 80 kg P₂O₅ ha⁻¹ with PSB 2 L ha⁻¹ (T₁₅) and 80 kg P₂O₅ ha⁻¹ with PSB 3 L ha⁻¹ (T₁₆). Each pot was uniformly basal-dressed with 30 kg N ha⁻¹ in the form of urea and DAP, with phosphorus applied according to the treatments.

PSB was applied as per the respective treatment. The soybean variety GJS-3 was sown in each pot with 5 seeds. Soil samples from each pot were collected at 30 DAS, 60 DAS, and at harvest. These samples were analyzed for available phosphorus (Olsen *et al.*, 1954), nitrogen (Alkaline permanganate method-Subbaiah and Asija, 1956), potassium (Flame photo metric method-jackson, 1973) and sulphur (Turbidimetric method-Williams and Steinbergs, 1959)

Results and Discussion

Effect of phosphorus on soil available nutrients

Different phosphorus doses significantly influenced phosphorus availability (Table 2) at various growth stages, with 80 kg P₂O₅ ha⁻¹ (P₃) showing the highest values *i.e.*, 40.24 kg ha⁻¹, 35.90 kg ha⁻¹ and 37.56 kg ha⁻¹ at 30 DAS, 60 DAS, and at harvest, respectively. These values were comparable to those obtained with P₂ (60 kg P₂O₅ ha⁻¹), which showed values of 38.77 kg ha⁻¹, 34.51 kg ha⁻¹ and 36.05 kg ha⁻¹ at the same stages. In contrast, the lowest phosphorus availability was observed in the control (P₀) at all three stages. The higher phosphorus availability under the P₃ and P₂ treatments can be attributed to the adequate supply of phosphorus, which met the crop's demand. Additionally, phosphorus application promoted microbial activity in the rhizosphere by fostering the development of a fibrous and deep root system, which helped recycle nutrients from the deeper soil layers to the upper layers. Similar results were earlier reported by Kamble *et al.* (2006), Solanki *et al.* (2015), Singh (2010), Swaroop (2006) in cowpea.

But application of different phosphorus levels did not exert any significant effect (Table 1) on available nitrogen, potassium, and sulphur content in soil at harvest. However, the highest values of N (240.79), K (293.40) and S (14.04) were recorded at P₃ (80 kg ha⁻¹) but remained statistically non-significant across all phosphorus levels.

Effect of Phosphorus Solubilizing Bacteria

The application of phosphorus-solubilizing bacteria (PSB) at 3 L PSB ha⁻¹ (PSB₃) significantly enhanced phosphorus availability (Table 2), with values of 40.08 kg ha⁻¹, 35.82 kg ha⁻¹ and 37.41 kg ha⁻¹ at 30 DAS, 60 DAS, and at harvest, respectively. These results were similar to those obtained with the application of PSB₂ (2 L PSB ha⁻¹), which recorded 38.76 kg ha⁻¹, 34.46 kg ha⁻¹ and 36.26 kg ha⁻¹ at the same stages. In comparison, the lowest phosphorus availability was observed in the control treatment (PSB₀) at all three stages. The highest phosphorus availability in the soil was observed with the application of 3 L PSB ha⁻¹, which can be attributed to the increased phosphate solubilization by the PSB. This

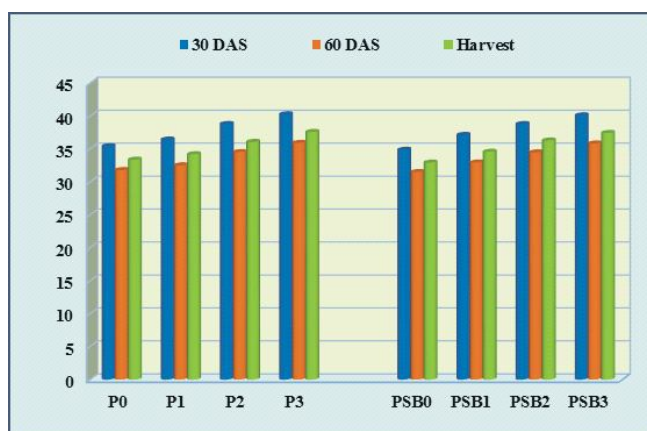


Fig. 1 : Effect of phosphorus and PSB on soil available phosphorus at 30, 60 DAS and at harvest.

Table 1 : Effect of phosphorus and PSB on available nitrogen, potassium, sulphur at harvest of the crop.

Treatments	Soil available nutrient		
	N (kg ha ⁻¹)	K ₂ O (kg ha ⁻¹)	S (ppm)
Phosphorus (P)			
P ₀ : 0 kg P ₂ O ₅ ha ⁻¹	226.55	293.40	14.04
P ₁ : 40 kg P ₂ O ₅ ha ⁻¹	229.99	296.40	14.06
P ₂ : 60 kg P ₂ O ₅ ha ⁻¹	236.81	300.00	14.08
P ₃ : 80 kg P ₂ O ₅ ha ⁻¹	240.79	305.40	14.17
S.Em. ±	3.87	4.47	0.22
C.D. at 5%	NS	NS	NS
Phosphorus Solubilizing Bacteria (PSB)			
PSB ₀ : PSB 0 L ha ⁻¹	228.17	296.10	14.03
PSB ₁ : PSB 1 L ha ⁻¹	233.23	298.50	14.07
PSB ₂ : PSB 2 L ha ⁻¹	235.50	299.70	14.10
PSB ₃ : PSB 3 L ha ⁻¹	237.25	300.90	14.14
S.Em. ±	3.87	4.47	0.22
C.D. at 5%	NS	NS	NS
P x PSB			
S.Em. ±	7.75	8.93	0.43
C.D. at 5%	NS	NS	NS
C.V.%	5.74	5.18	5.34

solubilization is driven by the production of non-volatile organic acids, which act as powerful chelating agents. These acids form stable complexes with Ca, Mg, Fe and Al, thereby making these nutrients more accessible to plants. Similar results were reported by Sarawgi *et al.* (2012), Yasmeen and Bano (2014), Rahangdale *et al.* (2021) in soybean crop.

But different levels of phosphorus solubilising bacteria did not exert any significant effect on nitrogen, potassium, and sulphur availability at harvest.

Table 2 : The impact of phosphorus and phosphorus solubilizing bacteria (PSB) on the availability of phosphorus in soil at 30 DAS, 60 DAS and harvest was evaluated.

Treatments	Soil available phosphorus (P ₂ O ₅ kg ha ⁻¹)		
	30 DAS	60 DAS	At harvest
Phosphorus (P)			
P ₀ : 0 kg P ₂ O ₅ ha ⁻¹	35.39	31.78	33.35
P ₁ : 40 kg P ₂ O ₅ ha ⁻¹	36.41	32.50	34.17
P ₂ : 60 kg P ₂ O ₅ ha ⁻¹	38.77	34.51	36.05
P ₃ : 80 kg P ₂ O ₅ ha ⁻¹	40.24	35.90	37.56
S.Em. ±	0.59	0.53	0.54
C.D. at 5%	1.70	1.53	1.56
Phosphorus Solubilizing Bacteria (PSB)			
PSB ₀ : PSB 0 L ha ⁻¹	34.86	31.48	32.91
PSB ₁ : PSB 1 L ha ⁻¹	37.11	32.93	34.55
PSB ₂ : PSB 2 L ha ⁻¹	38.76	34.46	36.26
PSB ₃ : PSB 3 L ha ⁻¹	40.08	35.82	37.41
S.Em. ±	0.59	0.53	0.54
C.D. at 5%	1.70	1.53	1.56
P x PSB			
S.Em. ±	1.18	1.07	1.08
C.D. at 5%	NS	NS	NS
C.V.%	5.43	5.48	5.31

Interaction effect of Phosphorus and PSB on available phosphorus

The application of different phosphorus and PSB treatments did not significantly affect N, K, S availability at harvest and phosphorus availability in the soil at 30 DAS, 60 DAS and at harvest.

Conclusion

Phosphorus fertilization and PSB application significantly improved soil phosphorus availability in soybean. The highest values were recorded with 80 kg P₂O₅ ha⁻¹ and 3 L PSB ha⁻¹, while their interaction remained non-significant, indicating independent effects. These findings suggest that the combined use of adequate phosphorus fertilization and PSB inoculation is a viable approach to enhance soil nutrient availability and sustain soybean productivity.

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