International Journal of Plant & Soil Science

Volume 36, Issue 7, Page 362-370, 2024; Article no.IJPSS.117578
ISSN: 2320-7035

Combined Impact of Phosphorus Solubilizng Bacteria and Single Super Phosphate on Soil Nutrient Availability in Sunflower and Chickpea

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2024/v36i74741

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/117578

Original Research Article

Received: 01/04/2024
Accepted: 05/06/2024
Published: 11/06/2024

ABSTRACT

A field experiment was conducted to study the effect of different doses and method of phosphate solubilizing bacteria (PSB) application and the phosphorus levels on sunflower and chickpea during *Rabi,* 2020 at College of Agriculture, PJTSAU, Rajendranagar, Hyderabad. The experiment was laid out in Randomized Block Design, comprising eleven treatments with three replications. Initial soil parameters of experimental site indicated that the soil belongs to sandy loam texture, with alkaline

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Cite as: Mudigiri , Chandana, A. Aziz Qureshi, S. Harish Kumar Sharma, and S. Triveni. 2024. "Combined Impact of Phosphorus Solubilizng Bacteria and Single Super Phosphate on Soil Nutrient Availability in Sunflower and Chickpea". International Journal of Plant & Soil Science 36 (7):362-70. https://doi.org/10.9734/ijpss/2024/v36i74741.

in soil reaction, non-saline, low in organic carbon (OC), low in available nitrogen, medium in available phosphorus, available potassium and available sulphur. The results indicated that there was an increase in soil fertility status *viz*., organic carbon (%), available nitrogen, phosphorus, potassium and sulphur with the combined application of the Phosphorus Solubilizng Bacteria (PSB) and Phosphorus (P) fertilizers over the single application of the P levels. Within the PSB application significant results were obtained with the Soil application compared to the drenching.

Keywords: Available nutrients; drenching; phosphorus solubilizing bacteria; soil application.

1. INTRODUCTION

Sunflower (*Helianthus annus* L.) belongs to the family *Asteraceae* and is characterized by considerable decor ability, as production of heads varying in the different cultivars by size and colour of the flower, from cream to yellow. It is a potential source of edible oil, ranges with 48 - 52 % of good quality edible oil (FAO). The global sunflower seed, oil and meal production in the year 2018-19 was estimated at 51.41 mt, 19.45 mt and 20.90 mt. In India during *Rabi* 2018-19 sunflower had occupied 1.145 lakh hectares area, while in Telangana it occupies 2030 ha. In Telangana, Siddipet with an area of 1226 ha is the major sunflower producing district.

Chickpea (*Cicer arietinum L*.) is a multipurpose pulse crop consumed by the people in different forms. Chickpea is one of the major *rabi* pulse crop. Among, the pulses chickpea is known as "King of pulses'. In India, it occupies about 9.18 millionhectare area with production of 8.22 million tones and an average productivity of 900 kg ha^{-1}. In India 2017-18, chickpea was cultivated in about 106 lakh hectare with productivity of 1056 kg ha^{-1}. In Telangana the area contributed for chickpea cultivation was 1.03 lakh hectare and production of 1.50 lakh tones.

Phosphorus (P) is the second most abundantly required plant nutrient element after nitrogen to crop plants. Phosphorus positively affects the sunflower growth and productivity by increasing photosynthetic rate and the radiation use efficiency and consequently the availability of assimilates [1]. Phosphorus nutrient in legumes stimulates a greater attention in increasing the productivity, as it encourages healthy root growth and promotes rhizobial activity resulting in increased nodulation that exemplify nitrogen fixation. Phosphate solubilizing bacteria (PSB) enhances phosphorus availability to plants by lowering soil pH by microbial production of organic acids and mineralization of organic phosphorus. Introduction of PSB in the rhizosphere of crop also increases the efficiency of phosphate fertilizers [2]. Most of the soils in Telangana are low in available phosphorus status, farmers are using high amount of DAP fertilizer, to reduce the cost on fertilizer and also to increase the availability of soil fertility like O.C, N, P, K and S present study has been investigated.

2. MATERIALS AND METHODS

The experiment was conducted during *Rabi*, 2020 and the geographical location of the experimental site was 17° 19'20.3658" N Latitude, 78° 24'30.1176" E Longitude with an altitude of 477 m above mean sea level. Agro-climatologically the area is classified as Southern Telangana Agro Climatic Zone of Telangana state.

Table 1. Experimental details

Technical details	Experiment I	Experiment II
Season	*Rabi*, 2020	*Rabi,* 2020
Design	Simple RBD	Simple RBD
Treatment	11	11
Replication	03	03
Crop	Sunflower	Chickpea
Varities	KBSH – 78	NBeG-252
Seed rate	5 kg ha-^{1}	40 kg ha^{-1}
Spacing	60 x 30cm	30 x 10 cm
Duration	98 days	105 days
RDF	60:90:30 kg ha-^{1} NPK	30:60:0 kg ha^{-1} NPK
Gross plot size	4.8 x 3 m^{2}	4.8 x 3 m^{2}
Net plot size	3.6 X 2.4 m^{2}	4.2 X2.8 m^{2}

Fig. 1. Satellite view of the field

The experimental soil was sandy loam in texture, alkaline in soil reaction, non - saline, low in OC and available nitrogen, medium status of available phosphorus, available potassium and available sulphur. The experiment was laid out in RBD comprising eleven treatments with three replications. The experimental details are given in Tables 1 and 2.

Table 2. Treatment details

Treatment	Treatment detail
T_1	100% NPK, (RDF)
T_2	No P
T_3	No P + PSB-D
T_4	No P +PSB-SA_1
T_5	No P + PSB-SA_2
T_6	75 % P + PSB-D
T_7	75 % P+ PSB-SA_1
T_8	75 % P + PSB-SA_2
T_9	50% P + PSB-D
T_{10}	50% P+ PSB-SA_1
T_{11}	50% P + PSB-SA_2

D - Drenching @ 50 ml L^{-1} or 8 L ha^{-1}.
SA_1 - Soil application of PSB @ 3 kg ha^{-1}
SA_2 - Soil application of PSB @ 6 kg ha^{-1}

PSB was applied as soil application and drenching at the time of sowing. Lignite based powder form with two doses @ 3 and 6 kg per hectare was properly mixed with vermicompost @ 1 t ha^{-1} was applied to soil in the sowing line. The liquid PSB @ 8 L per hectare was drenched in the sowing line.

2.1 Fertilizer Application

a) Sunflower

Urea was applied in two splits, 30 kg of urea at the time of sowing as I st split and 30 kg of urea at 45 DAS as II nd split. The entire dose of SSP as per treatment was applied at time of sowing. Murate of potash (30 kg) was applied at the time of sowing.

b) chickpea

Urea was applied in two doses, 1 st dose (30 kg) at the time of sowing. The entire dose of SSP as per treatment was applied at the time of sowing.

2.2 Organic Carbon

It was determined by the procedure given by Walkley and Black method [3].

Organic carbon (%) = vol of $K_2Cr_2O_7$ x[(B-S)/B] X 100/ weight of soil

B= blank titre value   S = sample titre value.

2.3 Available Nitrogen

Available nitrogen in soil samples was determined by using Alkaline permanganate method as described by Subbaiah and Asija, [4]. The procedure involves distilling the soil with alkaline potassium permanganate solution and determining the ammonia liberated by titrating against standard sulphuric acid (0.02 *N*).

Available N (kg ha-1) = 2.24 x 10^6 x 100 x Y x 0.00014 / [20 x 100]

1 ml of 0.01 *N* H_2SO_4 = 0.00014

Y ml = volume of 0.02 *N* H_2SO_4 utilized for neutralizing of NH_3.

2.4 Available Potassium

Available potassium was extracted from soil using neutral normal ammonium acetate and potassium present in the extracts was determined by using Flame photometer (Elico CL 378) as described by Jackson [5] and expressed as kg K_2O ha^{-1}.

Available K (kg ha^{-1}) = Concentration of K x volume made x 100 x 2.24 x 10^6 / (10^6 x weight of sample x 100)

2.5 Available Sulphur

Available sulphur was extracted from the soil by employing 0.15 percent $CaCl_2.2H_2O$ solution using 1:5 soil to solution ratio. The S content in the extract was determined by the turbidimetric method of Chesnin and Yien [6].

Available sulphur (ppm) = Vol of 0.15% $Cacl_2$ x vol made x Absorbance x conc from graph(ppm) / (Weight of soil x Aliquot taken)

3. RESULTS AND DISCUSSION

3.1 Sunflower

3.1.1 Soil organic carbon

Data regarding the soil organic carbon (%) after harvest of crop has been presented in Table 3 and depicted in Fig. 4. The results in Table 3 indicate significant increase in the organic carbon content due to PSB application over the initial status of soil (0.41%), this was mainly due to the application of PSB, along with Vermicompost @ 1t/ha was applied this might have increased microbial activity and exudates which improved soil organic matter *i,e.,* increase in organic carbon content. There was a significant increase in the soil organic carbon with the increase in phosphorus levels up to 75% P level. 50% P, (100% NK) + PSB was at par with the 100% NPK. Hence, saving the cost of 25% phosphorus levels. As already mentioned that vermicompost improves the physical and biological properties of soil including supply of almost all essential plant nutrients for growth and development of plant, thus balanced nutrition under favorable environment might have helped in better growth and development of plants. These results are in agreement with the findings that application of SSP with PSB can substantially increase soil organic matter [7].

3.1.2 Available soil nitrogen

Data pertaining to the available nitrogen content of the soil after harvest of crop was presented in Table 3 and Fig 2, revealed that there was an increase in the available nitrogen content over initial soil status (143.6 kg N ha^{-1}). The maximum nitrogen content was noticed in T8 (187.87 kg ha^{-1}) treatment, treated with 75% P, +PSB – SA_2 and lowest available nitrogen was recorded in T_2 (156.93 kg ha-1) treatment, treated with No P. However, the effect was found to be non-significant. The nitrogen content was very similar in all the treatments of phosphorus levels. Raghuveer *et al.* [8] reported that application of phosphorus at different levels and PSB strains to the soil did not significantly influence available nitrogen. These results were in accordance with findings of Egamberdiyeva et al. (2004), Raghuveer et al. [8] and Sipai et al. [9].

3.1.3 Available potassium

The data in the Table 3 and Fig 2 indicate that there was a non- significant effect of PSB and P levels on available soil potassium content. The K content was found to be increased compared to the initial soil status (166 kg K ha^{-1}).The highest potassium in soil after harvest of crop was noticed in the T_1 treatment (215.15 kg K ha^{-1}) , treated with (100% NPK) and the lowest was reported in T_4 (178.14 kg K ha^{-1}) treatment, treated with No P + PSB – SA_1 . It has been shown that the concentration of K in the soil is increased by the regulation of organic acid metabolism and Hþ secretion by PSB (Li et al., 2020a). Our results are in agreement with findings that the application of P can increase the K content in soil (Sharma *et al.,* 2011) and Estrada-Bonilla *et al.* [10].

3.1.4 Available sulphur

From the results, at maturity stage the available sulphur content increased with the application of P levels and PSB as seen in Table 3and Fig 2. There was an increase in available sulphur over the initial status of soil (22.91 ppm). Among all the treatments, highest available sulphur was seen in T_1 (33.69 mg/kg) with 100% NPK as shown in Figure 1. As source of P levels was single super phosphate highest available sulphur was seen in T_1. With the application of vermicompost also increases the sulphur content this might be due to indirect addition of sulphur.

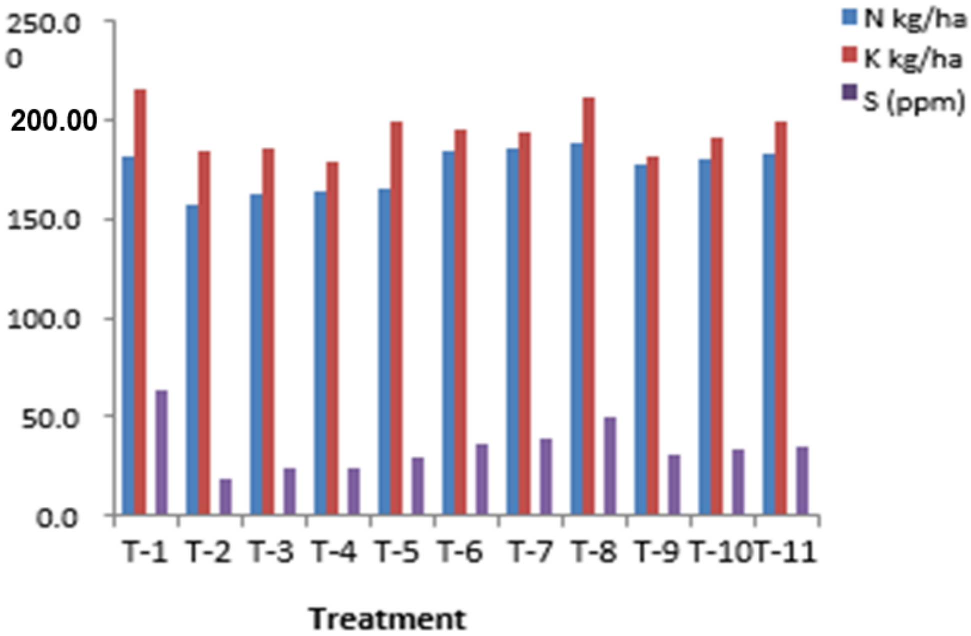

Fig. 2. Soil fertility parameters after harvest of sunflower due to different doses and methods of PSB application and P levels

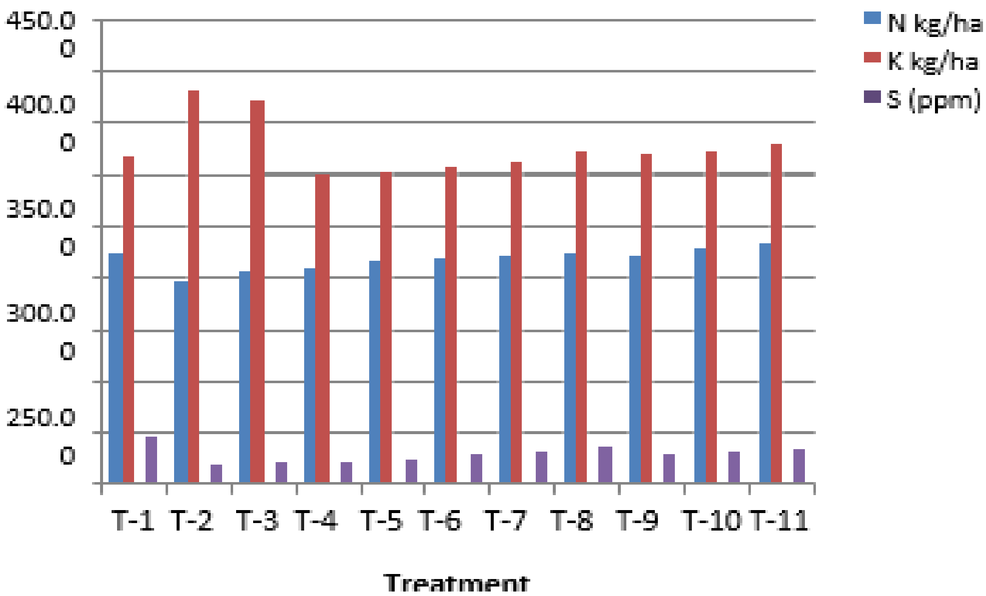

Fig. 3. Available Soil fertility parameters after harvest of Chickpea due to different doses and methods of PSB application and P levels

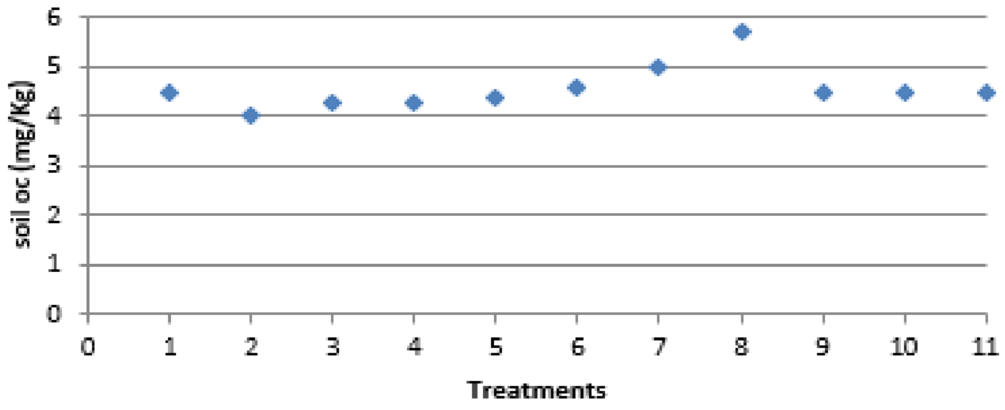

Fig. 4. Available Oc (mg/Kg) after harvest of sunflower

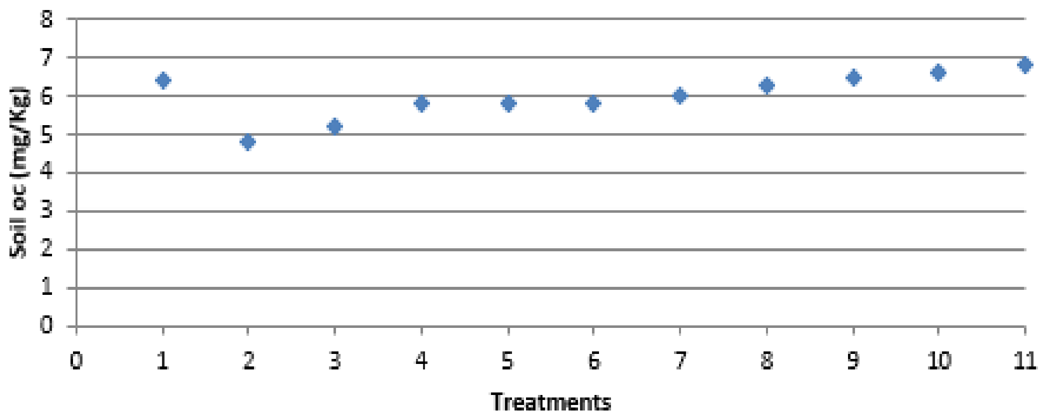

Fig. 5. Available OC (mg/Kg) after harvest in chickpea

Table 3. Effect of different doses and methods of PSB application and P levels on soil available parameters of Sunflower after harvest

Treatment	Soil fertility status at maturity stage of sunflower				
	Soil O.C (mg/kg)	Soil N (kg N ha^{-1})	Soil P (kg P ha^{-1})	Soil K (kg K ha^{-1})	Soil S (ppm)
T_1	4.5	181.05	16.45	215.17	33.69
T_2	4.0	156.93	13.08	184.48	24.5
T_3	4.3	161.93	14.18	184.83	24.63
T_4	4.3	164.43	14.16	178.13	24.80
T_5	4.4	165.67	15.02	199.77	29.36
T_6	4.6	183.83	15.70	194.88	28.26
T_7	5.0	184.87	17.19	193.39	30.5
T_8	5.7	187.87	19.23	211.62	26.30
T_9	4.5	176.73	15.72	181.81	31.15
T_{10}	4.5	180.73	15.97	191.20	32.44
T_{11}	4.5	182.33	16.11	199.73	28.40
SEm ±	0.01	5	0.7	9.41	1.4
CD (0.05)	0.03	NS	1.9	NS	NS
CV%	5.6		7.2		

Table 4. Effect of different doses and methods of PSB application and P levels on soil fertility parameters at harvest of Chickpea

Treatment	Soil fertility status at maturity stage of chickpea				
	Soil O.C (mg/kg)	Soil N (kg ha^{-1})	Soil P (kg P ha^{-1})	Soil K (kg ha^{-1})	Soil S (mg/kg)
T_1	6.4	224.93	27.2	382.11	37.00
T_2	4.8	197.13	18.5	317.11	21.15
T_3	5.2	207.47	19.5	372.82	21.28
T_4	5.8	210.17	20.6	299.61	22.76
T_5	5.8	216.80	22.5	302.06	25.16
T_6	5.8	220.11	23.1	308.61	29.67
T_7	6.0	222.67	24.1	312.33	32.99
T_8	6.3	223.47	27.3	321.29	36.88
T_9	6.5	222.31	28.3	320.51	30.60
T_{10}	6.6	229.37	29.5	321.37	32.33
T_{11}	6.8	234.57	30.7	330.33	33.63
SEm±	0.02	4.1	0.72	2.2	0.9
CD(0.05)	0.06	NS	2.14	NS	NS
CV%	5.69		5.09		

3.2 Chickpea

3.2.1 Soil organic carbon

Data regarding the soil organic carbon (mg/kg) after harvest of crop was presented in Table 4 and Fig. 5. From the Table 4, there was an increase in the organic carbon content over the initial soil status (0.41mg/kg), it was mainly due to the application of PSB, both as a drenching and soil application. Along with the PSB, vermicompost @ 1 kg /plot were applied leading to increase in the soil organic matter *i.e.,* increase in organic carbon content. There was a significant increase in the soil organic carbon with the increase in phosphorus levels up to 50% P level. 50% P + PSB-6 kg/ha (0.68mg/kg) was at par with the 100% NPK (0.64mg/kg). These results are in agreement with the findings that application of SSP with PSB can substantially increase soil organic matter khan et al. 2022.

3.2.2 Available soil nitrogen

Data pertaining to the available soil Nitrogen, treated with different doses and methods of PSB and P levels was presented in Table 4 and Figure 3. From the Table 4, there was an increase in available Nitrogen over the initial soil status (187.5 kg N ha^{-1}). The available nitrogen has a non-significant effect with PSB and P levels. The maximum nitrogen content at maturity stage of chickpea was registered in T_{11} (234.57 kg N ha^{-1}) treated with phosphorus level of 50% P + PSB – SA_2 and the lowest was noticed in T_2 (197.13 kg N ha^{-1}), No P. However, the effect was found to be non-significant. With the application of PSB there was an increase in availableN status increased with increase in the levels of P and bio levels (PSB and AM). This might be attributed to the application of P and bio levels which enhanced and established better root system. Nutrients possibly stimulate the nodulating bacteria for more fixation of atmosphere N_2 resulting in increase of its contents in the soil over control. These results were supported by findings of Kumar *et al*., [11,12].

3.2.3 Available potassium

According to the data in the Table 4 and Figure 3, the available potassium status in the soil had a non-significant effect with PSB and P levels. The available potassium status of soil decreased compared to the initial soil status (420 kg ha^{-1}). Highest soil potassium was seen in the treatment T_1 (382.11 kg K ha^{-1}) and lowest potassium content of soil was observed in T_4 (299 .61 kg K ha^{-1}).

3.2.4 Available soil sulphur

Available sulphur content of the soil was not significantly influenced due to application of PSB and P levels after harvest of crop as shown in Table 4 and Fig 3. The sulphur content at maturity stage ranged from 21.15 to 37 mg/kg. Though, it was a non-significant but increase in the sulphur content was noticed it was mainly due to the source of P levels *i.e.,* Single super phopshtae. Highest sulphur content was noticed in T_1 (37 mg/kg), 100% NPK and lowest was noticed in T_2 (21.15 mg/kg) i.e., No P.

Non-significant variation observed in sulphur content of the soil might be due to conversion of unavailable form of sulphur to available form. With the application of vermicompost also there was increase in sulphur, because it indirectly adds the sulphur.

4. CONCLUSION

With the application of PSB, increased P availability resulting in substantial P-fertilizer savings for the P-deficient soils. PSB enhanced sunflower and chickpea yield and mineral concentrations beyond levels that could be obtained with P-fertilizer addition alone. We conclude that PSB increases soil P availability, enhance P-fertilizer-use efficiency, reduce overall P-fertilizer costs, and enhance yield and nutritional value. There was an increase in the soil fertility status due to the application of the PSB over the 100% RDF. Due to the application of the PSB there was highest N,P,K and S obtained in the 75% application of the fertilizer. Hence, saving of the 25% fertilizer was seen in sunflower. In chickpea highest Soil N,P,K and S was obtained in the 50% NPK+ PSB application . Hence, saving of the 50% of the applied fertilizer. Further studies are required to determine the efficiency of PSB microorganisms insolubilizing P sources under multiple soil conditions and to better understand the additional benefits of these microorganisms beyond their P-solubilizing capacity, as well as economic feasibility of microorganism addition for varies crops.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models

(ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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