

Effect of Phosphorus and Bioinoculants on Soil Fertility, Nutrient Content and Uptake of Black gram (*Vigna mungo* L.)

ABSTRACT

Being a leguminous crop black gram requires a generous amount of phosphorus for its growth and development as phosphorus is one of the primary macronutrients. Through biological nitrogen fixation, black gram can improve the fertility status of the soil. Bioinoculants promote growth by improving nutrient uptake and making the nutrients more easily available to the host plant's root hairs. To investigate the effect of phosphorus and bioinoculants on soil fertility, nutrient content, and uptake of black gram a field study was conducted at the university farm of Lovely Professional University during the summer season (2023). The experiment was laid out in a randomized block design with nine treatment combinations (T₁- control, T₂- 20 kg P₂O₅ha⁻¹, T₃- 40 kg P₂O₅ha⁻¹, T₄-20 kg P₂O₅ha⁻¹+PSB, T₅-40 kg P₂O₅ha⁻¹+PSB, T₆-20 kg P₂O₅ha⁻¹+VAM, T₇-40 kg P₂O₅ha⁻¹+VAM, T₈-20 kg P₂O₅ha⁻¹+PSB+VAM, T₉-40 kg P₂O₅ha⁻¹+PSB+VAM), each replicated thrice. Based on analysis, the results demonstrated that the application of 40 kg P₂O₅ ha⁻¹+PSB+VAM(T₉) had a greater availability of nitrogen (188.63 kg ha⁻¹), and phosphorus (32.68 kg ha⁻¹) over control (176.04 and 19.41 kg ha⁻¹) respectively. The maximum nitrogen (3.88 and 1.64 %) and phosphorus content (0.408 and 0.228 %) in grain and stover were also observed in the T₉ (40 kg P₂O₅ ha⁻¹+PSB+VAM) treated plots when compared to control (3.19 and 1.3%, 0.309 and 0.141%) respectively. Similarly, the maximum total nitrogen and phosphorus uptake (80.04 and 9.71 kg ha⁻¹) was observed in T₉ over control (31.09 and 3.19 kg ha⁻¹) respectively.

Comment [T1]: writing chemical formulas is standardized.

Comment [T2]: You state based on the results of the statistical analysis. Looking visually, there is no visible difference among treatments.

Comment [T3]: writing chemical formulas is standardized.

Comment [T4]: How about the availability and uptake of potassium? In your result, you explain about potassium availability and uptake.

Keywords: Phosphorus; Phosphate Solubilizing Bacteria (PSB); VAM (Vesicular Arbuscular Mycorrhiza); Soil fertility; Nutrient content and uptake

1. INTRODUCTION

Legumes are crucial for sustainable agriculture due to their capacity to enhance soil fertility and health. With a symbiotic association with some bacteria in soil, legumes can improve nitrogen through biological nitrogen fixation. The extended utilization of input-intensive technologies in the cultivation of rice-wheat and rice-rice cropping patterns has resulted in the depletion of natural resources. The issue of declining productivity needs to be addressed urgently, as it threatens the sustainability of these cropping systems[1]. Pulses are important source of amino acids and protein for diets, particularly for vegetarians. About 14% of the total protein in an average Indian diet comes from pulses[2]. Black gram [*Vigna mungo* L.] is a highly nutritious and important grain legume crop in India that is cultivated over a wider range of agro-climatic zones of the country. It occupies about 48.38 lakh hectares area in the country producing 27.28 lakh tons of grain with average productivity of 564 kg ha⁻¹[3]. It contains 24 % protein, 60 % carbohydrate, and 1.3% fat on a dry weight basis.

Comment [T5]: writing symbols is standardized

Comment [T6]: writing symbols is standardized

Phosphorus is an essential nutrient for all living organisms and no other nutrient can perform its functions. It is a crucial element for plant growth and development and is classified as a primary macronutrient. This means that crops require it in relatively high quantities[4]. It is referred to as the “key of life” and the essential functions of Phosphorus are “energy storage” and transfer of energy (ADP and ATP), which act as “energy currency”. Phosphorus also plays a crucial role in the development of the symbiotic relationship between legumes and bacteria.

Comment [T7]: Pay attention to the use of spaces throughout the body of the text.

Comment [T8]: Pay attention to the use of spaces throughout the body of the text.

Bioinoculants contain living microorganisms that colonize the rhizosphere or the interior of the plant and stimulate growth by enhancing nutrient uptake and making the nutrients easily accessible to plant root hairs of the host plant. They play a pivotal role in solubilizing the inorganic phosphates in soil and making them accessible to plants and they are crucial for maintaining crop production, preserving soil health, and promoting biodiversity. The solubilization of soil P is facilitated by Phosphate Solubilizing Bacteria (PSB) that can solubilize inorganic phosphorus from insoluble compounds. It has been demonstrated that PSB inoculation increases P uptake and crop production by altering the plants' P-acquisition strategy, thereby changing the P content in the roots and stems of plants, and the bioavailable P concentration in the soil[5]. Mycorrhiza is a symbiotic relationship between a unique class of fungi and plant roots that promotes phosphorus translocation and uptake in plants[6]. These fungi have been found to enhance the growth and yield of most field crops by increasing the absorption of phosphorus. Additionally, VAM biofertilizers have been proven effective in improving the availability of major and trace elements for plants. They also prevent pathogens from penetrating plant roots and protect the plant roots from

Comment [T9]: Haven't seen the complete phrase before.

biotic and abiotic stresses[7].Considering the above facts the present experiment was undertaken to investigate the effects of phosphorus and bioinoculants on black gram.

2.MATERIALS AND METHODS

The experiment was conducted at the University farm of Lovely Professional University, Phagwara, District Kapurthala during the summer season (2023).The farm is situated at 31°25' N latitude and 75°E longitude with 225 m average elevation from above mean sea level. Hot and dry summer prevails with an annual precipitation ranging from 577-748 mm. During the crop growing period, the maximum temperature was 36.12°C and minimum temperature was 20.1°C, rainfall was 52 mm, and relative humidity was 45.5 %. The soil of the experimental field was sandy loam in texture with 51 % coarse sand, 33% silt, 16 % clay, pH of 7.61, EC (0.47 dsm⁻¹), OC (0.57%), available nitrogen (182.9 kg ha⁻¹), available phosphorus (25.95 kg ha⁻¹) and available potassium (191.87 kg ha⁻¹). The experiment was laid out in randomized block design with nine treatment combinations (T₁- control, T₂- 20 kg P₂O₅ ha⁻¹, T₃- 40 kg P₂O₅ ha⁻¹, T₄-20 kg P₂O₅ ha⁻¹+PSB, T₅-40 kg P₂O₅ ha⁻¹+PSB, T₆-20 kg P₂O₅ ha⁻¹+VAM, T₇-40 kg P₂O₅ ha⁻¹+VAM, T₈-20 kg P₂O₅ ha⁻¹+PSB+VAM, T₉-40 kg P₂O₅ ha⁻¹+PSB+VAM), each replicated thrice. The black gram variety Mash 1008 was sown @ 20 kg ha⁻¹ in a plot size of 5x3 m² with a spacing of 30 x 10 cm² at a depth of 4-6 cm. The seeds were inoculated @ 2 ml kg⁻¹ seed of liquid PSB culture according to the treatments, using a jaggery solution of 1 liter. The VAM was applied with field soil @ 5 kg ha⁻¹ and incorporated into crop rows at the time of sowing to bulk the carrier as per treatment and thoroughly mixed manually in the plots. Before sowing the treated seeds were kept for shade drying for 30 minutes. A uniform dose of nitrogen @ 12.5 kg ha⁻¹ was applied through urea and phosphorus was applied through SSP as per the treatment as a basal dose at the time of sowing to all the plots except the control plot. The soil samples were collected from each experimental plots at a depth of 0-15 cm before sowing and after the harvest of the crop. The soil samples were air-dried, followed by grinding to pass through a 2 mm sieve. Furthermore, to determine the available N, P₂O₅, and K₂O as per the procedures [Available N -Alkaline permanganate method (Subbiah and Asija, 1956) [8], Available P₂O₅-Olsen's method [9], Available K₂O-Flame photometric method (Metson, 1956) [10]] the soil samples were tested. The plant and grain samples were oven-dried after threshing. Furthermore, the samples were ground to pass through 40-mesh sieves for analysis of their [N-Kjeldahl's method (Snell and Snell, 1949) [11], P-Vanadomolybdo phosphoric acid, yellow color method (Jackson, 1973) [12], and (Tri-acid digested material by using Flame

Comment [T10]: How and where did you get the mycorrhiza? and what genus or species did you use?

Comment [T11]: How many PSB population/dose do you use? And you explain species of PSB you use.

Comment [T12]: SSP ?

Comment [T13]: deleted

photometer(Jackson,1973)][12]content.The data of available nitrogen,phosphorus,and potassium in the soil,nutrient content,and their uptake were further statistically analyzed by applying the analysis of variance (ANOVA) method With a significance level of 5%($P=0.05$).The nutrient uptake was calculated by using the following formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)}=\frac{\text{yield (kg ha}^{-1}\text{)}\times\text{nutrient content(\%)}}{100}$$

3.RESULT AND DISCUSSION

3.1Effect of phosphorus and bioinoculants on availability of Nitrogen, Phosphorus, and potassium in soil

3.1.1 Available Nitrogen (kg ha⁻¹)

Further scrutinizing the data, it becomes evident that the T₉(40 kgP₂O₅ha⁻¹+ PSB+VAM) had greater availability of nitrogen(188.63 kg ha⁻¹) which was 7.15 and 5.35% higher than control(T₁) and T₂(20 kgP₂O₅ha⁻¹).The outcomes could be the consequences of applying bioinoculants to the soil,which increased soil fertility by converting unavailable nitrogen into available forms so that plants can use. These findings correspond with the observations reported by[13]and [14].By cycling the nutrient N, PSB helps in the maintenance and restoration of fertility of the soil, which in turn results in improved soil fertility. The process includes biotic and abiotic elements with PSB that are thought to be among the primary biotic factors influencing the N cycle in the soil [i.e., converting N₂-fixation into plant-available NH₃; nitrification process(converting NH₄⁺ into NO₂)[15].On the other basis,Phosphorus plays a pivotal role in root growth, proliferation, and nodule formation. The atmospheric nitrogen is fixed within these nodules through biological nitrogen fixation (BNF) which is conciliated by nitrogen-fixing rhizobia. An increased number of nodules may lead to greater nitrogen fixation, ultimately enhancing the fertility of soil.

Comment [T14]: In the method, you analyze Anova, however you do not explain the ANOVA results on this parameter.

Comment [T15]: Reference?

Comment [T16]: don't describe things you didn't analyze or observe.

3.1.2 Available Phosphorous (kg ha⁻¹)

It was clear from looking at the data that the availability of phosphorus in soil was enhanced by 14.06,45.56, and 68.36% by applying 40kgP₂O₅ha⁻¹+PSB+VAM (T₉) over T₃(40 kgP₂O₅ha⁻¹)T₂(20 kgP₂O₅ha⁻¹),and control(T₁) respectively.Being statistically at par with each other, the treatmentsT₇(30.69kg ha⁻¹) and T₅(30.66kg ha⁻¹),T₄(24.79kg ha⁻¹), and T₆(24.8kg ha⁻¹) also improved the availability of phosphorus in soil than control.Bioinoculants effectively solubilize phosphorus by extracting acids such as glutamic, lactic, succinic, glyoxalic, oxalic, fumaric, malic, formic, a-ketobutric, and propionic acid.The hydroxyl-acids, in particular, can

form chelates which can effectively solubilize phosphates. These bioinoculants not only solubilize phosphates but also have the ability to mineralize organic phosphorus, releasing more P into soil solution that is necessary for plant growth and metabolism. This could be due to the PSB inoculation increasing soil nutrient availability. The results correlate with the findings reported by [16]. The dual inoculation of PSB and VAM substantially improved the availability of phosphorus in soil [17].

Comment [T17]: don't describe things you didn't analyze or observe.

Comment [T18]: What is that?

3.1.3 Available potassium (kg ha^{-1})

Upon analyzing the data, the results indicated that of application of potassium and bioinoculants did not have any significant impact (Table 1) on the availability of this nutrient.

Comment [T19]: How do you explain this potassium result?

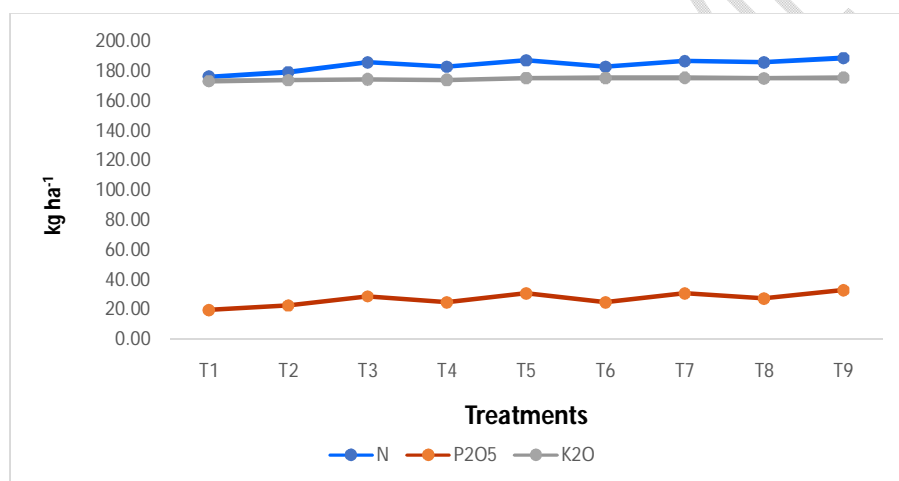
Comment [T20]: You don't explain in the method if you use potassium, there were nitrogen, phosphorus and bioinoculants. Application of potassium → treatment or not?

Table 1: Effect of phosphorus and bioinoculants on availability of Nitrogen, Phosphorus, and potassium in the soil

Tr.no.	Treatments	Available N (Kg ha^{-1})	Available P_2O_5 (Kg ha^{-1})	Available K_2O (Kg ha^{-1})
T ₁	Control	176.04	19.41	173.11
T ₂	20 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$	179.05	22.45	173.75
T ₃	40 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$	185.77	28.65	174.22
T ₄	20 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$ + PSB	182.69	24.79	173.95
T ₅	40 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$ + PSB	187.09	30.66	175.16
T ₆	20 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$ + VAM	182.74	24.80	175.23
T ₇	40 $\text{kg P}_2\text{O}_5\text{ha}^{-1}$ + VAM	186.41	30.69	175.33

T ₈	20 kg P ₂ O ₅ ha ⁻¹ + PSB+ VAM	185.70	27.11	174.84
T ₉	40 kgP ₂ O ₅ ha ⁻¹ + PSB+ VAM	188.63	32.68	175.40
	SE(m)±	0.93	0.66	1.04
	C.D.(P=0.05)	2.79	1.98	NS

PSB-Phosphorus,Phosphate Solubilizing Bacteria;VAM- Vesicular Arbuscular Mycorrhiza



Comment [T21]: avoid presenting repetitive data (graphs or tables)

Fig 1: Effect of phosphorus and bioinoculants on availability of Nitrogen, Phosphorus, and potassium in soil

3.2 Effect of phosphorus and bioinoculants on nutrient content and uptake

3.2.1 Nitrogen content and uptake

After a comprehensive analysis, the results demonstrated that the treatment T₉ exhibited the highest nitrogen content in grain and stover (3.88 and 1.64%) than control (T₁) (3.19 and 1.3%) and T₂ (3.59 and 1.45%) respectively. A similar pattern was followed in the case of nutrient uptake of the plant. The application of 40 kgP₂O₅ha⁻¹ + PSB+ VAM (T₉) showed a substantial increase in nitrogen uptake in grain and stover (41.86 and 38.17 kg ha⁻¹) respectively. On the contrary, the control plot attained the lowest uptake of nitrogen (15.96 and 15.14 kg ha⁻¹)

Comment [T22]: Unit?

Comment [T23]: Unit?

¹)respectively.Among the other treatments,T₃ was found at par with T₈,T₄also remained at par with T₆.The conclusions from this experiment correspond with the findings reported by [18].The application of increasing levels of P fertilizer (from 20 to 40 kg ha⁻¹) resulted in higher plant N content in mungbean. The findings corroborate the observations recorded by [19] and [20]. The nitrogen content in grain and stover might have increased due to the synergistic effect between P and N that might have resulted in more nitrogen absorption and uptake by the plant.The improved accessibility of nitrogen in the root zone,in conjunction with enhanced cellular metabolic activity, may have augmented the nutrient uptake and their accumulation in the plant's vegetative parts[13].

3.2.2 Phosphorous content and uptake

A perusal of the data described that the utilization of phosphorus and bioinoculants had a significant effect on the phosphorus levels found in both the grains and stover. The concentration of P in grain and stover showed a significant increase with the successive dose of P. Upon a thorough examination, it becomes evident that the phosphorus content in the grain and stover (0.408 and 0.228%) of black gram was highest under T₉ when compared to control (0.309 and 0.141%) and T₂ (0.354 and 0.174%) respectively followed by T₇ (0.393 and 0.216%) which remained statistically at par with T₅ (0.392 and 0.215%) respectively. A similar trend was also observed in the case of the uptake of phosphorus. The T₉ showcased the highest uptake of phosphorus in grain and stover (4.4 and 5.3 kg ha⁻¹) than control (1.55 and 1.64 kg ha⁻¹) respectively. The higher content of nutrients also showed a significant and positive correlation with yield. These consequences correlate with the observations reported by [21]. Plants that undergo improved metabolism tend to accumulate a higher amount of essential nutrients in their vegetative parts. This, in turn, facilitates more efficient translocation of these nutrients to the reproductive organs of the crop. As a result, the grains and stover of the crop plant show a significant increase in nutrient content at the time of harvest of the crop. The uptake of nutrients is closely linked with the increased nutrient content and higher yield in both the grain and stover. This, in turn, leads to higher nutrient uptake by both grain and stover [18].

3.2.3 Potassium content and uptake

The information regarding the effect of the phosphorus and bioinoculants displayed that the treatment combinations had no significant impact on the concentration of potassium in grain

Comment [T24]: Show the ANOVA data!

Comment [T25]: Unit?

Comment [T26]: Show the correlation analysis!

and stover. As per the discussion in the earlier paragraph, nutrient uptake is related to nutrient content and grain and stover yield. So, a higher yield may have increased the uptake of potassium. The maximum uptake in grain and stover was observed in T₉ (9.11 and 42.58 kg ha⁻¹). Whereas, the control plot exhibited the lowest uptake (4.01 and 20 kg ha⁻¹) respectively.

Comment [T27]: Where is grain and stover yield? If you want to make this statement, you must show the data of yield grain and stover.

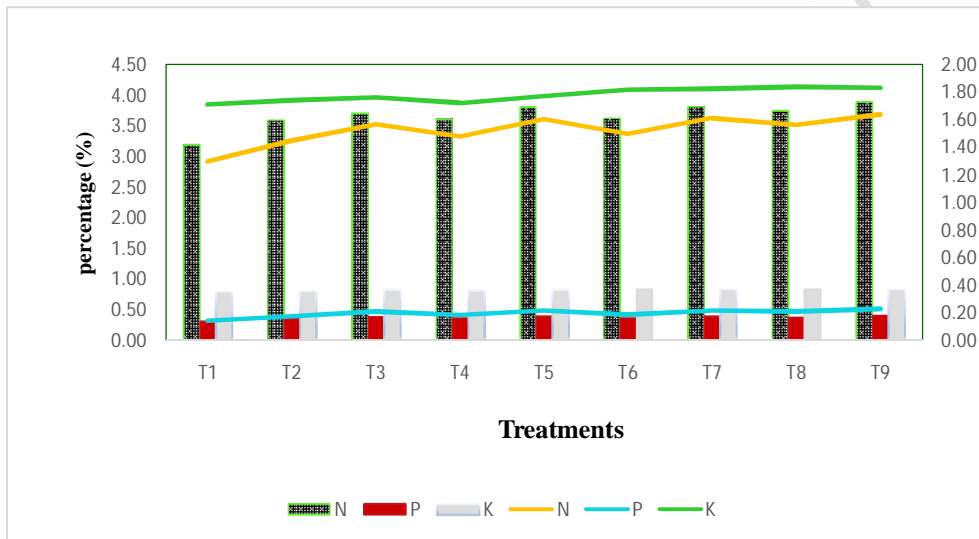
Table 2: Effects of phosphorus and bioinoculants on nutrient content of black gram

Tr.no	Treatments	Nitrogen content(%)		Phosphorus content (%)		Potassium content (%)	
		Grain	Stover	Grain	Stover	Grain	Stover
T ₁	Control	3.19	1.3	0.309	0.141	0.801	1.71
T ₂	20 kgP ₂ O ₅ ha ⁻¹	3.59	1.45	0.354	0.174	0.809	1.74
T ₃	40 kgP ₂ O ₅ ha ⁻¹	3.70	1.57	0.38	0.210	0.831	1.76
T ₄	20 kgP ₂ O ₅ ha ⁻¹ + PSB	3.60	1.48	0.366	0.183	0.821	1.72
T ₅	40 kg P ₂ O ₅ ha ⁻¹ + PSB	3.80	1.60	0.392	0.215	0.837	1.77
T ₆	20 kgP ₂ O ₅ ha ⁻¹ + VAM	3.62	1.50	0.367	0.185	0.842	1.81
T ₇	40 kgP ₂ O ₅ ha ⁻¹ +VAM	3.81	1.61	0.393	0.216	0.843	1.82
T ₈	20 kgP ₂ O ₅ ha ⁻¹ +PSB+ VAM	3.74	1.56	0.379	0.209	0.841	1.84
T ₉	40 kgP ₂ O ₅ ha ⁻¹ + PSB+ VAM	3.88	1.64	0.408	0.228	0.844	1.83

	SE(m)±	0.02	0.007	0.002	0.001	0.012	0.032
	C.D.(P=0.05)	0.059	0.021	0.006	0.003	NS	NS

PSB-Phosphorus, Phosphate Solubilizing Bacteria; VAM- Vesicular Arbuscular Mycorrhiza

Comment [T28]: present analytical data that is easy to understand.

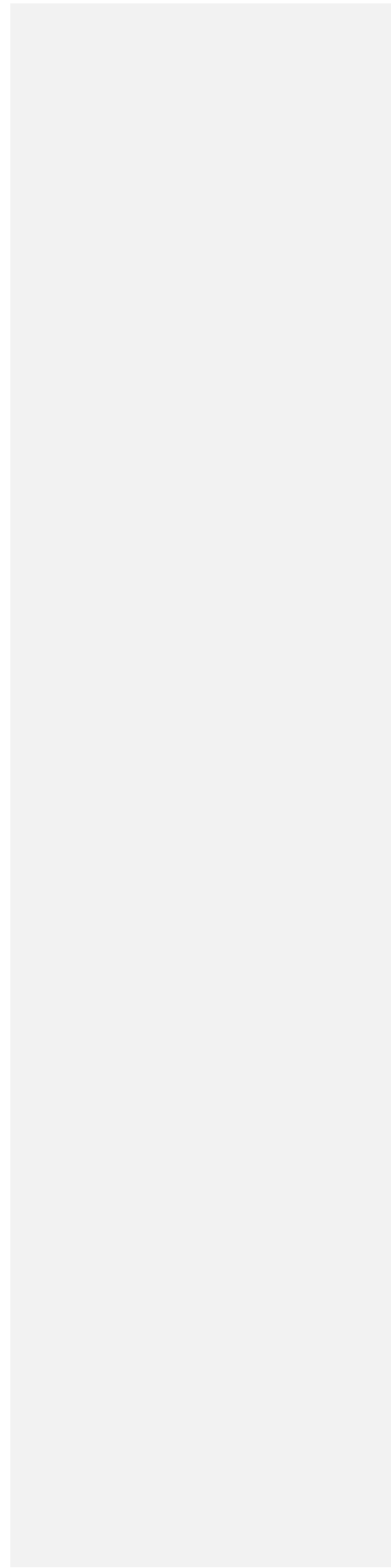


Comment [T29]: avoid presenting repetitive data (graphs or tables)

Fig 2: Effects of phosphorus and bioinoculants on nutrient content of black gram

UNDER

UNDER PEER REVIEW



Tr.no.	Treatments	Nitrogen Uptake (kg ha ⁻¹)			Phosphorus Uptake (kg ha ⁻¹)			Potassium Uptake (kg ha ⁻¹)		
		Grain	Stover	Total	Grain	Stover	Total	Grain	Stover	Total
T ₁	Control	15.96	15.14	31.09	1.55	1.64	3.19	4.01	20.00	24.01
T ₂	20 kg P ₂ O ₅ ha ⁻¹	21.58	19.97	41.56	2.13	2.40	4.53	4.87	24.01	28.88
T ₃	40 kgP ₂ O ₅ ha ⁻¹	31.93	29.25	61.18	3.29	3.93	7.21	7.17	32.87	40.04
T ₄	20 kgP ₂ O ₅ ha ⁻¹ + PSB	25.67	23.50	49.17	2.61	2.91	5.52	5.85	27.32	33.17
T ₅	40 kgP ₂ O ₅ ha ⁻¹ + PSB	36.54	33.39	69.93	3.77	4.47	8.23	8.04	36.86	44.90
T ₆	20 kg P ₂ O ₅ ha ⁻¹ + VAM	26.93	24.20	51.13	2.73	2.99	5.72	6.27	29.34	35.62
T ₇	40 kgP ₂ O ₅ ha ⁻¹ + VAM	37.37	34.07	71.44	3.85	4.58	8.44	8.27	38.52	46.78
T ₈	20 kgP ₂ O ₅ ha ⁻¹ + PSB+VAM	31.63	28.57	60.20	3.20	3.82	7.03	7.11	33.61	40.72
T ₉	40 kgP ₂ O ₅ ha ⁻¹ + PSB+VAM	41.86	38.17	80.04	4.40	5.30	9.71	9.11	42.58	51.69
	SE(m)±	1.12	1.02	1.82	0.121	0.123	0.214	0.324	1.40	1.58
	C.D.(P=0.05)	3.38	3.06	5.46	0.364	0.369	0.641	0.971	4.2	4.74

Table-3:Effect of Phosphorus and bioinoculants on nutrient uptake of black gram

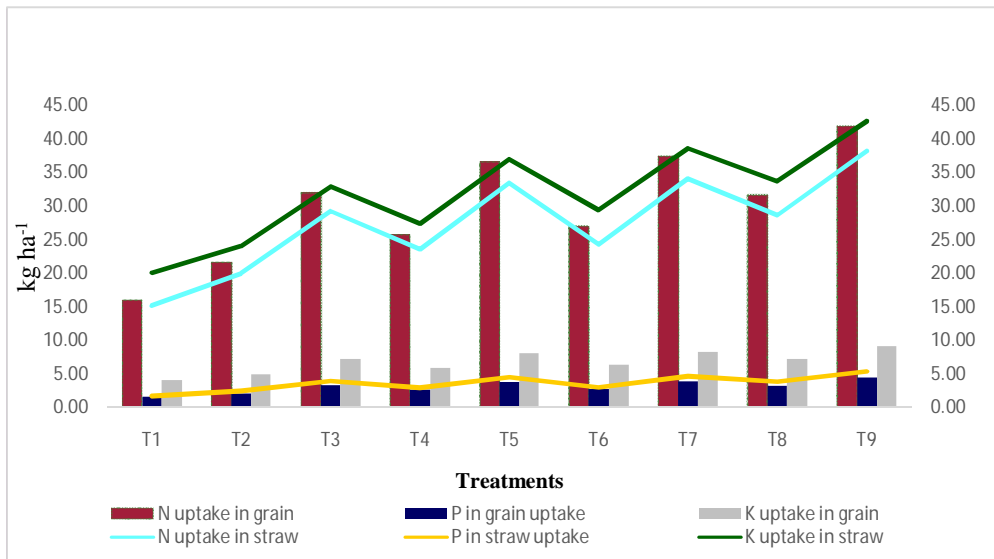


Fig 3: Effects of phosphorus and bioinoculants on nutrient uptake of black gram

CONCLUSION

Based on one one-year experiment, it may be concluded that the application of $40 \text{ kgP}_2\text{O}_5\text{ha}^{-1}$ along with combined inoculation of PSB and VAM was found effective in improving the fertility status of the soil. The enhanced fertility status of the soil may have resulted in greater nutrient content and their uptake by plants. So, cultivation of black gram with $40 \text{ kgP}_2\text{O}_5\text{ha}^{-1}$ + PSB + VAM can be a beneficial approach in maintaining soil health as well as in nutrient absorption and their utilization by the crop.

Comment [T30]: avoid presenting repetitive data (graphs or tables)

Comment [T31]: ?

Comment [T32]: What is the soil fertility status based on? adjust it to your results and discussion.

Comment [T33]: Is the conclusion based on the results of ANOVA and further tests? because it would be in vain if this recommendation turns out to be insignificant with treatment without bioinoculant.

REFERENCES

Comment [T34]: Use references tool

1. Majee A, Maji S, Bhowmick UR, Mondal S. Effect of Zinc Nutrition on Lathyrus (*Lathyrussativus* L.) under Varying Sowing Dates in the Gangetic Plains. Legume Research- An International Journal.;1:6.
2. Kant S, Kumar A, Kumar S, Kumar V, Pal Y, Shukla AK. Effect of rhizobium, PSB and p- levels on growth, yield attributes and yield of Urdbean (*Vigna mungo* L.). J Pure Appl Microbiol. 2016 Dec 1;10(4):3093-8.
3. DES, Ministry of Agriculture and Farmers Welfare (DA&FW), GoI, 2022-23)
4. Chtouki M, Naciri R, Oukarroum A. A review on phosphorus drip fertigation in the Mediterranean region: Fundamentals, current situation, challenges, and perspectives. Heliyon. 2024 Feb 3.
5. Rafi MM, Krishnaveni MS, Charyulu PB. Phosphate-solubilizing microorganisms and their emerging role in sustainable agriculture. Recent developments in applied microbiology and biochemistry. 2019 Jan 1:223-33.
6. Nath Bhowmik S, Das A. Biofertilizers: a sustainable approach for pulse production. Legumes for soil health and sustainable management. 2018:445-85.
7. Bhatt SS, Vamshi M, Singh V, Rani P, Dayal D. Ameriolations with VAM and PSB Inoculation of Growth and Yield Attributes in Pea (*Pisum sativum* L.) cv. Arkel. Legume Research- An International Journal.;1:5.
8. Subbiah BV, Asija GL. A rapid procedure for the estimation of available nitrogen in soils.
9. Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. US Department of Agriculture; 1954.
10. Metson AJ. Methods of chemical analysis for soil survey samples. Soil Science. 1957 Mar 1;83(3):245.
11. Snell PD, Snell GT. Colorimetric methods of analysis, 3rd Edn. II D Van Nostrand Co. Inc. New York. 1949.
12. Jackson ML. Soil chemical analysis, pentice hall of India Pvt. Ltd., New Delhi, India. 1973;498:151-4.

Comment [T35]: Year?

Comment [T36]: Year?

13. Dutta S, Singh M, Meena RK, Onte S, Basak N, Kumar S, Meena VK. Effect of organic and inorganic nutrient sources on growth, yield, nutrient uptake and economics of fodder cowpea [*Vigna unguiculata* (L.) Walp.]. Legume Research-An International Journal. 2021;44(9):1046-52.

14. Goud VV, Kale HB. Productivity and profitability of pigeonpea under different sources of nutrients in rainfed condition of Central India. Journal of food legumes. 2010;23(3and4):212-7.

15. Bender SF, Wagg C, van der Heijden MG. An underground revolution: biodiversity and soil ecological engineering for agricultural sustainability. Trends in ecology & evolution. 2016 Jun 1;31(6):440-52.

16. Naragund R, Singh YV, Jaiswal P, Bana RS, Choudhary AK. Influence of crop establishment practices and microbial inoculants on nodulation of summer green gram (*Vigna radiata*) and soil quality parameters. Legume Research-An International Journal. 2022;45(5):646-51.

17. Dadhich LK, Gupta AK, Sharma HS. Yield and quality of clusterbean as influenced by molybdenum and phosphorus.

Comment [T37]: Year?

18. Khangarot AK, Yadav SS, Shyanabhoga SP, Verma RS, Jakhar R, Bhawariya A. Effect of prom and microbial inoculants on growth, yield and nutrient uptake of mungbean [*Vignaradiata* (L.) wilczek]. Legume Research-An International Journal. 2022;45(6):756-61.

19. Sipai AH, Jat HS, Rathore BS, Sevak K, Jodha JS. Effect of phosphorus, sulphur and biofertilizer on productivity and soil fertility after harvest of moongbean grown on light textured soil of Kachchh. An Asian Journal of Soil Science. 2015 Dec 1;10(2):228-36.

20. Khan H, Akbar WA, Shah Z, Rahim HU, Taj A, Alatalo JM. Coupling phosphate-solubilizing bacteria (PSB) with inorganic phosphorus fertilizer improves mungbean (*Vignaradiata*) phosphorus acquisition, nitrogen fixation, and yield in alkaline-calcareous soil. Heliyon. 2022 Mar 1;8(3).

21. Yadav M, Yadav SS, Kumar S, Yadav T, Yadav HK. Effect of Phosphorus and Bio-fertilizers on Growth and Yield, of Urdbean (*Vigna mungo* (L.) Hepper). International Journal of Plant & Soil Science. 2017;18(5):1-7.

UNDER PEER REVIEW

