



Effect of Phosphorus and Bioinoculants on Nutrient Uptake and Available Soil Nutrients by Black Gram (*Vigna mungo* L.)

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Authors' contributions

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

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ABSTRACT

Aims: To investigate the effect of phosphorus and bioinoculants on nutrient uptake and available soil nutrients by black gram.

Study Design: Randomized Block Design.

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Place and Duration of Study: Agronomy farm of Lovely Professional University, Phagwara, Punjab during summer (2023).

Methodology: The experiment comprised of 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.

Results: The results demonstrated that the application of 40 kg P₂O₅ha⁻¹+PSB+VAM (T₉) recorded the highest soil available nitrogen (188.63 kg ha⁻¹), and phosphorus (32.68 kg ha⁻¹) compared to all other treatments. The maximum nitrogen content in grain and stover (3.88 % and 1.64 %) and phosphorus content in grain and stover (0.408 % and 0.228 %) were also overserved in the T₉ (40 kg P₂O₅ ha⁻¹+PSB+VAM) treated plots. Similarly, T₉ treated plots recorded the highest uptake of nutrients in grain and stover *i.e.*, nitrogen (41.86 and 38.17 kg ha⁻¹), phosphorus (4.4 and 5.3 kg ha⁻¹), and potassium (9.11 and 42.58 kg ha⁻¹).

Conclusion: The cultivation of black gram by applying 40 kg P₂O₅ ha⁻¹+PSB+VAM can be beneficial for the restoration of soil available nutrients, nutrient content and uptake of black gram.

Keywords: Black gram; phosphorus; PSB; VAM; soil fertility; nutrient content; 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 an 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.

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.

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 phosphorous 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, Vesicular Arbuscular Mycorrhiza 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 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 Agronomy farm of Lovely Professional University, Phagwara (Punjab) 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 the 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(0.47dsm⁻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 *i.e.*, 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. The black gram variety Mash 1008 was sown @ 20 kg ha⁻¹ in a plot size of 5x3 m² with a spacing of 30 x10 cm² at a depth of 4-6cm. 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 Single Super Phosphate (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 plot 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 [8], Available P₂O₅-Olsen's method [9], Available K₂O-Flame photometric method [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 [11], P-Vanadomolybdo phosphoric acid, yellow colour method [12], and (Tri-acid digested material by using Flame photometer [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.

Nutrient uptake (kg ha⁻¹) =

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

3. RESULTS AND DISCUSSION

3.1 Effect 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 treated plots significantly enhanced the availability of nitrogen (188.63 kg ha⁻¹) which was 7.15% and 5.35% higher than control(T₁) and T₂. The results may be the outcomes of applying bioinoculants to the soil, which increases soil fertility by converting unavailable nitrogen into available forms so that plants can use. These findings align with the observations reported by [13]and [14].

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 40 kg P₂O₅ha⁻¹ PSB + VAM (T₉) over T₃(40 kg P₂O₅ha⁻¹), T₂(20 kg P₂O₅ha⁻¹), and control(T₁). Being statistically at par with each other, the treatments T₇(30.69 kg ha⁻¹) and T₅

(30.66 kg ha⁻¹), T₄(24.79 kg ha⁻¹), and T₆(24.8 kg ha⁻¹) also improved the availability of phosphorus in soil than control. This may be because bioinoculants, such as Phosphate Solubilizing Bacteria enhance phosphorus availability in soil by converting unavailable phosphorus into forms that plants can readily absorb. They can solubilize insoluble phosphates by the secretion of organic acids or release of protons, production of chelating substances Secretion of phosphatases, and enzymes that release phosphate ions from organic compounds in the soil. Secretion of organic acids lowers the pH and dissolves phosphate compounds. Chelating substances lock phosphates in insoluble forms. Secretion of phosphatases, enzymes that release phosphate ions from organic compounds in the soil. This could be due to the PSB inoculation increasing soil nutrient availability. The results are close in line with the findings reported by [15].

3.1.3 Available potassium (kg ha⁻¹)

Upon analyzing the data, the results indicated that these treatment combinations did not have any significant effect on the availability of potassium (Fig. 1).

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 (3.19 % and 1.3%) and T₂ (3.59 % and 1.45%). A similar pattern was followed in the case of nutrient uptake of the plant. The application of 40 kg P₂O₅ha⁻¹+ PSB+ VAM(T₉) showed a significant increase in nitrogen uptake in grain and stover (41.86 and 38.17 kg ha⁻¹) respectively. On the contrary, the control plot(T₁) attained the lowest uptake of nitrogen (15.96 and 15.14 kg ha⁻¹) respectively. Among the other treatments, T₃ was found at par with T₈, T₄ also remained at par with T₆. 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].

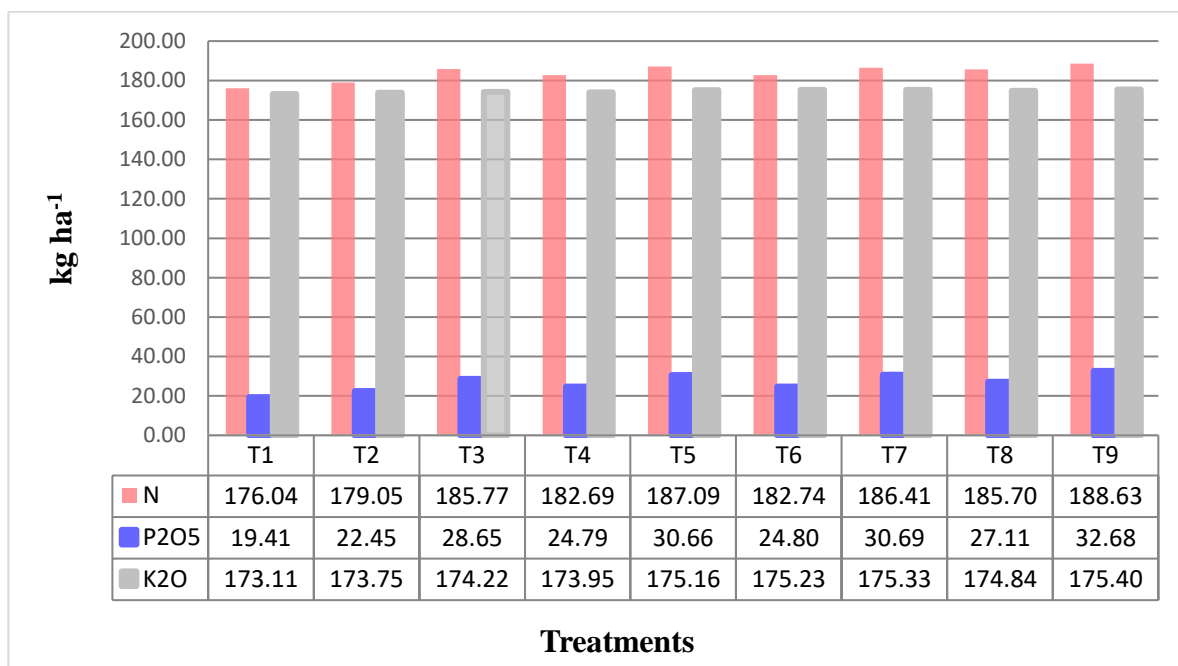


Fig. 1. Effect of phosphorus and bioinoculants on the availability of nitrogen, Phosphorus, and potassium in soil

Table 1. Effect of phosphorus and bioinoculants on nutrient content of black gram

Tr.no.	Treatment	Nitrogen content (%)		Phosphorus content (%)		Potassium content (%)	
		Grain	Stover	Grain	Stover	Grain	Stover
T1	Control	3.19	1.30	0.309	0.141	0.801	1.71
T2	20 kg P ₂ O ₅ ha ⁻¹	3.59	1.45	0.354	0.174	0.809	1.74
T3	40 kg P ₂ O ₅ ha ⁻¹	3.70	1.57	0.38	0.210	0.831	1.76
T4	20 kg P ₂ O ₅ ha ⁻¹ + PSB	3.60	1.48	0.366	0.183	0.821	1.72
T5	40 kg P ₂ O ₅ ha ⁻¹ + PSB	3.80	1.60	0.392	0.215	0.837	1.77
T6	20 kg P ₂ O ₅ ha ⁻¹ + VAM	3.62	1.50	0.367	0.185	0.842	1.81
T7	40 kg P ₂ O ₅ ha ⁻¹ + VAM	3.81	1.61	0.393	0.216	0.843	1.82
T8	20kg P ₂ O ₅ ha ⁻¹ + PSB+ VAM	3.74	1.56	0.379	0.209	0.841	1.84
T9	40 kg P 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

Table 2. Effect of phosphorus and bioinoculants on nutrient uptake of black gram

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 kg P 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 kg P 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 kg P 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 kg P 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 kg P 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 kg P 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

3.2.2 Phosphorous content and uptake

A perusal of the data described that the application 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%) followed by T₇ (0.393% and 0.216%) which remained statistically at par with T₅ (0.392% and 0.215%). 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). 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. VAM forms a symbiotic relationship with the roots of the plant. The mycorrhizal fungi extend the root system via their hyphal networks, which can access and absorb nutrients from a larger soil volume. This symbiosis improves the uptake of phosphorus. Similar findings were reported by [16] and [17].

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 content of potassium in grain and stover. 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 in grain and stover (4.01 and 20 kg ha⁻¹). The increase in potassium uptake may be due to the combined inoculation of PSB and VAM along with phosphorus can have an additive effect leading to better nutrient use efficiency. The presence of VAM can increase the effectiveness of PSB in solubilizing phosphorus, which in turn can boost potassium uptake as part of improved overall nutrient acquisition [17].

4. CONCLUSION

Based on a one-year experiment, it may be concluded that cultivation of black gram with 40 kg P₂O₅ha⁻¹+PSB +VAM can be a beneficial approach in maintaining soil health as well as in nutrient absorption and their utilization by the crop especially for the central plain region of Punjab.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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