

EFFECT OF PHOSPHORUS LEVELS, PHOSPHORUS SOLUBILIZING BACTERIA AND AM FUNGI ON GROWTH YIELD AND ECONOMICS OF IRRIGATED BLACKGRAM

ABSTRACT

Aims: This study investigates the effect of phosphorus and biofertilizer management on growth and yield of irrigated blackgram.

Study design and Methodology: The treatment was imposed in randomised block design (RBD) with 12 treatments and 3 replications.

Place and Duration of study: The study took place in Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India. The research was conducted from January - April 2025. VBN-8 variety was chosen for the experiment.

Results: The results of the experiment revealed that among various treatments involved, 60 kg P_2O_5 ha⁻¹ + seed treatment and soil application of PSB + AM fungi (T₁₂) recorded the highest values of plant height of 50.79 cm, LAI of 4.29, effective root nodules of 44.76, number of branches plant⁻¹ of 9.78 and dry matter production of 2197 kg ha⁻¹, seed yield of 102 kg ha⁻¹ and haulm yield of 1449 kg ha⁻¹. The application of 40 kg P_2O_5 with seed treatment and soil application of PSB and AM fungi (T₁₁) recorded the highest B:C ratio of 2.63 with gross income of Rs. 87,943 and net returns of Rs. 54,559 ha⁻¹.

Conclusion: The application of 60 kg P_2O_5 ha⁻¹ along with seed treatment and soil application of PSB and AM fungi (T₁₂) recorded the highest values across most parameters, including growth traits, yield attributes and both seed and haulm yield of blackgram. In terms of economics, application of 40 kg P_2O_5 ha⁻¹ + seed treatment and soil application of PSB and AM fungi (T₁₁) recorded highest benefit cost ratio. Based on the above experimental results, it may be concluded that the application of P_2O_5 @ 40 kg ha⁻¹ along with seed treatment and soil application of PSB and AM fungi (T₁₁) is an effective practice for yield maximization in irrigated blackgram.

Key words: blackgram, phosphorus, PSB, AM fungi

1. INTRODUCTION

Blackgram (*Vigna mungo* L.), commonly known as urad dal, is a vital pulse crop of the leguminosae family, indigenous to India. It is highly valued for its nutritional, economic and agronomic benefits, it serves as a staple protein source for humans and livestock. Its efficient root system supports soil structure and reduces erosion, contributing to sustainable farming systems (Swaminathan *et al.*, 2023). As of 2024, blackgram occupies 4.5 million hectares in India, yielding 1.2 million tonnes. In Tamil Nadu, it is cultivated over 0.35 million hectares with an annual production of 0.25 million tonnes and an average productivity of 714 kg ha⁻¹ (Directorate of Pulses Development, 2024 and Department of Agriculture and Farmers Welfare, 2024). To achieve higher yields in pulse crops, it is crucial to consider various factors

that impact crop management, including phosphorus nutrition. Phosphorus is the second essential macronutrient required for plant growth and development alongside nitrogen (Roch *et al.*, 2019). Phosphate uptake and yields are enhanced when phosphorus (P) is combined with phosphate-solubilizing microorganisms (PSMs), which play a crucial role in solubilizing phosphorus and making it available for plant uptake. The importance of PSMs has led to their use as biofertilizers, offering an eco-friendly and cost-effective way to improve phosphorus availability. PSBs are integral to improving crop productivity while minimizing environmental impact and dependency on chemical fertilizers (Meera *et al.*, 2022). Vesicular Arbuscular Mycorrhizal (VAM) fungi are crucial in enhancing plant growth and productivity by forming symbiotic relationships with plant roots, which significantly improve nutrient acquisition, particularly phosphorus. Incorporating VAM fungi into agricultural practices not only improves crop productivity but also promotes sustainable farming by reducing dependence on chemical fertilizers. This eco-friendly approach offers a promising strategy for improving the growth and yield of blackgram, making it a valuable addition to integrated nutrient management systems in legume cultivation (Suthar and Dange, 2022). Integration of phosphorus fertilization with PSB and VAM offers a synergistic approach to nutrient management. Studies report significant improvements in phosphorus availability, nodulation, nutrient uptake and yield in blackgram when inoculated with both PSB and AM fungi, either alone or in combination with reduced phosphorus levels. This integrated use of biofertilizers with chemical fertilizers aligns with sustainable agriculture practices, reducing dependency on synthetic inputs while maintaining soil health and productivity (Sahu *et al.*, 2020; Dharwe *et al.*, 2018). Considering the above, the study titled “Effect of phosphorus levels, PSB and AM fungi on irrigated blackgram” was conducted to evaluate their impact on growth, yield and economics.

2. MATERIALS AND METHODS

A field experiment was conducted at Experimental Farm, Department of Agronomy, Annamalai University, Annamalai Nagar, Chidambaram, Cuddalore district to study the during January to April-2025. The experimental farm is geographically located at 11°24'N latitude and 79°44'E longitude with an altitude of + 5.79 m above mean sea level (MSL). The weekly mean maximum temperature ranged from 30.0°C to 35.5°C with a mean of 32.77°C and the weekly mean minimum temperature from 18.5°C to 23.1°C with a mean of 20.21°C. The relative humidity ranged from 65 to 77 per cent with a mean of 71.33 per cent. The total rainfall received during the cropping period is 69.8 mm over 5 days. The experimental field soil was clay loam in texture, characterized by low available nitrogen, medium available phosphorus, and medium available potassium levels.

The experiment consists of 12 treatments *viz.* absolute control (T_1), seed treatment and soil application of PSB (T_2), seed treatment and soil application of AM fungi (T_3), seed treatment and soil application of PSB + AM fungi (T_4), 40 kg P_2O_5 ha⁻¹ (T_5), 60 kg P_2O_5 ha⁻¹ (T_6), 40 kg P_2O_5 ha⁻¹ + seed treatment and soil application of PSB (T_7), 60 kg P_2O_5 ha⁻¹ + seed treatment and soil application of PSB (T_8), 40 kg P_2O_5 ha⁻¹ + seed treatment and soil application of AM fungi (T_9), 60 kg P_2O_5 ha⁻¹ + seed treatment and soil application of AM fungi (T_{10}), 40 kg P_2O_5 ha⁻¹ + seed treatment and soil application of PSB + AM fungi (T_{11}), 60 kg P_2O_5 ha⁻¹ + seed treatment and soil application of PSB + AM fungi (T_{12}) and was laid in Randomized Block Design with three replications.

The biofertilizers, namely phosphobacteria and AM fungi, were applied at 10 packets each by thoroughly mixing with 25 kg of FYM and 25 kg of soil one day prior to sowing, according to the treatment schedule. Additionally, blackgram seeds were treated with phosphobacteria and AM fungi at the rate of 600 g/ha, 4 - 5 hours before sowing. A seed rate of 20 kg/ha was maintained, and seeds were dibbled at a spacing of 30 × 10 cm, with two seeds placed at a depth of 2 cm and covered with soil. A basal dose of 25 kg/ha nitrogen and 25 kg/ha potassium was uniformly applied to all plots, except the absolute control (T_1). Nitrogen was supplied through urea, while potassium was provided through muriate of potash. Phosphorus was applied as a basal dose through single super phosphate (SSP) for treatments T_5 to T_{12} , following the treatment schedule, excluding T_1 to T_4 .

The experiment was laid out in a Randomized Block Design (RBD) with three replications. Data collected on various parameters were analyzed using two-way ANOVA with the help of Statistical Package for Social Sciences (SPSS) software. The statistical procedures followed were as per the methods outlined by Gomez and Gomez (2010).

3. RESULTS AND DISCUSSION

3.1. Growth attributes

The study revealed significant variations in growth parameters such as plant height, leaf area index (LAI), number of branches per plant, crop growth rate (CGR), absolute growth rate (AGR), and dry matter production (DMP), as presented in Table 1. Among all treatments, application of 60 kg P₂O₅ ha⁻¹ + seed treatment and soil application of PSB + AM fungi (T₁₂) recorded the highest values for plant height (50.79 cm), LAI (4.29), effective root nodules (44.76), number of branches per plant (9.78) and dry matter production (2197 kg ha⁻¹) at the harvest stage. Similarly, the treatment with 40 kg P₂O₅ ha⁻¹ along with seed and soil application of PSB and AM fungi (T₁₁) also produced comparable results, highlighting the effectiveness of microbial inoculants in improving phosphorus uptake and utilization. The significant increase may be attributed to the application of phosphorus, which promoted overall plant growth and development by enhancing plant height, dry matter accumulation, and the number of branches per plant. This improvement can be linked to better functioning of the plant system and enriched rhizosphere nutrient environment, ultimately boosting photosynthetic efficiency and metabolic activity. These findings are in agreement with the report of Reddy *et al.*, (2025). PSB strains enhanced the availability of phosphorus in the soil by solubilizing insoluble forms, thereby facilitating greater phosphorus uptake by plants, which led to improved growth attributes. Similar findings were reported by Niraj and Prakash (2014), Madholiya (2015), Vidhyashree *et al.*, (2017), and Rabari *et al.*, (2022). The application of VAM fungi promoted overall plant development, particularly root and shoot growth, which likely facilitated greater nutrient absorption, enhanced photosynthesis, and increased assimilate production. This, in turn, contributed to improved plant height, higher nodule numbers, and greater dry matter accumulation. Similar results were reported by Bhabai *et al.*, (2019), Rathore *et al.*, (2023), and Choudhary *et al.*, (2024). Moreover, the lowest values for all growth parameters were recorded in the absolute control (T₁) plots, indicating the critical role of phosphorus and bio-inoculants in enhancing crop growth.

3.2. Yield attributes

The study revealed significant variations in yield parameters such as the number of pods per plant, seed yield, and haulm yield of blackgram, which were notably influenced by the different treatments, as presented in Table 2. The application of 60 kg P₂O₅ ha⁻¹ combined with seed treatment and soil application of PSB and AM fungi (T₁₂) resulted in the highest yield attributes, with 19.09 pods plant⁻¹, pod length of 5.88 cm, seed yield of 1026 kg ha⁻¹, and haulm yield of 1449 kg ha⁻¹, significantly outperforming the control. Similarly, the treatment involving 40 kg P₂O₅ ha⁻¹ along with PSB and AM fungi also recorded values close to T₁₂, highlighting the effectiveness of integrated phosphorus management with microbial inoculants in improving yield. This enhanced yield response may be attributed to the action of phosphate-solubilizing bacteria (PSB), which mobilize fixed forms of phosphorus by secreting organic acids such as formic and butyric acid, thereby increasing its availability to plants. The beneficial impact of biofertilizers observed in this study aligns with the findings of Selvakumar *et al.*, (2012), Kachave *et al.*, (2018), and Kumari *et al.*, (2020). Seed inoculation with biofertilizers contributes to nutrient supply through natural processes such as nitrogen fixation, phosphorus solubilization, and the production of growth-promoting substances, which collectively enhance yield attributes and seed yield in blackgram. Similar outcomes were reported by Bhabai *et al.*, (2019) and Rathore *et al.*, (2023). The application of phosphorus also accelerated the production and translocation of photosynthates from source to sink, leading to increased yield-contributing traits. This observation is supported by Parashar *et al.*, (2020). Furthermore, the formation of a more extensive root system, which improves water and nutrient uptake, was facilitated by the synergistic effects of PSB, AM fungi and basal phosphorus application. These factors collectively contributed to enhanced plant growth and yield performance, corroborating the findings of Jaga and Sharma (2015), Prajapati *et al.*, (2017), Biswas *et al.*, (2015), Yadav *et al.*, (2017) and Manna *et al.*, (2024). In contrast, the lowest seed yield was recorded in the absolute control treatment (T₁), which received neither phosphorus nor biofertilizers. This poor performance is likely due to inadequate nutrient availability and uptake, resulting in limited growth and productivity. Similar observations were reported by Singh *et al.*, (2020).

3.3. Economics

The economics of various treatment combinations was assessed using input-output analysis as presented in Table 2. The highest gross returns (Rs. 89,685 ha⁻¹), net returns (Rs. 55,301 ha⁻¹), and benefit-cost (B:C) ratio of 2.61 were observed with the application of 60 kg P₂O₅ ha⁻¹ along with seed treatment and soil application of PSB and AM fungi (T₁₂). Treatment T₁₁ (40 kg P₂O₅ ha⁻¹ + seed treatment and soil application of PSB + AM fungi) also produced comparable results, recording a gross return of Rs. 87,943 ha⁻¹, net return of Rs. 54,559 ha⁻¹ and the highest B:C ratio of 2.63. These economic

gains can be attributed to improved growth and yield parameters, resulting in higher seed and haulm yields due to adequate phosphorus nutrition. Phosphorus plays a vital role in energy transfer during photosynthesis, thereby enhancing photosynthetic efficiency and the production of assimilates, which ultimately contributes to greater economic returns. Similar findings were reported by Adjei-Nsiah *et al.*, (2018) and Harika *et al.*, (2023). The increase in gross and net profits, along with a higher B:C ratio, is a result of improved nutrient availability through the integrated use of phosphorus and biofertilizers, as supported by Yadav *et al.*, (2017), Tiwari *et al.*, (2022) and Singh and Debbarma (2023). Conversely, the absolute control (T₁) recorded the lowest gross return (Rs. 37,596 ha⁻¹), net return (Rs. 10,891 ha⁻¹), and B:C ratio (1.41), primarily due to the poor seed yield associated with the absence of phosphorus and biofertilizer application.

4. CONCLUSION

The application of 60 kg P₂O₅ ha⁻¹ combined with seed treatment and soil application of PSB and AM fungi (T₁₂) recorded the highest performance across most parameters, including growth traits, yield attributes, and both seed and haulm yield of blackgram. However, in terms of economics, the treatment with 40 kg P₂O₅ ha⁻¹ along with seed treatment and soil application of PSB and AM fungi (T₁₁) recorded the highest benefit-cost ratio. Based on the findings of this study, it can be concluded that the application of 40 kg P₂O₅ ha⁻¹ combined with PSB and AM fungi through seed treatment and soil application (T₁₁) is an effective strategy for maximizing yield in irrigated blackgram. This approach proves to be agronomically sound, environmentally sustainable, and economically beneficial for farmers.

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Table 1. Effect of phosphorus levels, PSB and AM fungi on growth attributes of irrigated blackgram

Treatment details	Growth attributes														
	Plant height (cm)			LAI		No. of branches	Effective root nodules		CGR (g m ⁻² day ⁻¹)		AGR (g plant ⁻¹ day ⁻¹)		DMP (kg/ha)		
	30 DAS	45 DAS	At harvest	30 DAS	45 DAS	At harvest	20 DAS	40 DAS	30-45 DAS	45 DAS-harvest	30-45 DAS	45 DAS-harvest	30 DAS	45 DAS	At harvest
T ₁	14.36	20.22	32.24	0.63	1.32	4.54	16.23	24.82	2.61	0.41	0.78	0.12	573	965	1026
T ₂	16.34	25.70	40.34	0.80	2.35	5.59	19.81	33.53	3.31	1.09	0.99	0.33	779	1275	1438
T ₃	15.27	24.33	38.66	0.71	2.01	5.09	18.52	31.98	3.23	0.74	0.97	0.22	698	1183	1294
T ₄	17.43	27.05	41.87	0.93	2.67	6.10	20.93	35.16	3.45	1.24	1.04	0.37	835	1353	1539
T ₅	18.53	28.48	43.16	1.09	3.06	6.65	22.14	36.64	3.90	1.35	1.17	0.41	902	1487	1690
T ₆	19.27	29.45	44.19	1.13	3.20	7.01	22.72	37.73	3.95	1.41	1.18	0.42	945	1537	1749
T ₇	21.86	32.92	47.58	1.54	3.82	8.44	25.21	41.36	4.16	1.75	1.25	0.52	1102	1726	1988
T ₈	22.48	33.91	48.57	1.58	3.94	8.83	25.80	42.40	4.19	1.79	1.26	0.54	1137	1765	2034
T ₉	20.17	30.76	45.36	1.25	3.47	7.54	23.68	39.09	4.05	1.55	1.22	0.46	1016	1624	1856
T ₁₀	20.95	31.72	46.33	1.31	3.61	7.91	24.23	40.12	4.09	1.61	1.23	0.48	1058	1672	1914
T ₁₁	23.42	35.31	49.80	1.83	4.18	9.42	26.73	43.68	4.26	2.09	1.28	0.63	1185	1824	2137
T ₁₂	24.22	36.24	50.79	1.88	4.29	9.78	27.25	44.76	4.31	2.15	1.29	0.65	1227	1874	2197
S.Ed	0.42	0.51	0.54	0.03	0.08	0.22	0.33	0.57	0.028	0.043	0.006	0.014	20.81	25.06	30.39
CD (p = 0.05)	0.88	1.06	1.12	0.07	0.17	0.45	0.68	1.18	0.06	0.09	0.013	0.03	43.17	51.98	63.03

Table 2. Effect of phosphorus levels, PSB and AM fungi on yield attributes of irrigated blackgram

Treatment details	Yield attributes						
	Number of pods plant ⁻¹	Pod length (cm)	Number of seeds pod ⁻¹	Test weight (g)	Seed yield (kg ha ⁻¹)	Haulm yield (kg ha ⁻¹)	Harvest index (%)
T ₁	4.86	3.70	3.15	4.52	428	788	35.20
T ₂	9.05	4.32	3.96	4.57	591	1023	36.62
T ₃	7.69	4.11	3.64	4.54	517	921	35.95
T ₄	10.48	4.58	4.38	4.61	657	1092	37.56
T ₅	11.81	4.81	4.72	4.65	734	1149	38.98
T ₆	12.76	4.89	4.96	4.67	750	1165	39.16
T ₇	16.05	5.49	5.98	4.75	936	1347	41.00
T ₈	16.98	5.57	6.19	4.79	957	1374	41.06
T ₉	13.93	5.16	5.43	4.69	818	1248	39.59
T ₁₀	14.84	5.25	5.62	4.71	836	1272	39.66
T ₁₁	18.27	5.79	6.53	4.81	1006	1427	41.35
T ₁₂	19.09	5.88	6.74	4.83	1026	1449	41.45
S.Ed	0.49	0.06	0.14	0.17	13.21	24.53	0.13
CD (p = 0.05)	1.02	0.12	0.29	NS	27.39	50.88	0.27

Table 3. Effect of phosphorus levels, PSB and AM fungi on economics of irrigated blackgram

Treatment details	Total cost of cultivation (Rs. ha ⁻¹)	Gross Income (Rs. ha ⁻¹)	Net Income (Rs. ha ⁻¹)	BCR
T ₁	26705	37596	10891	1.41
T ₂	31124	51849	20725	1.67
T ₃	31124	45383	14259	1.46
T ₄	31384	57594	26210	1.84
T ₅	32864	64273	31409	1.96
T ₆	33864	65665	31801	1.94
T ₇	33124	81843	48719	2.47
T ₈	34124	83676	49552	2.45
T ₉	33124	71596	38472	2.16
T ₁₀	34124	73168	39044	2.14
T ₁₁	33384	87943	54559	2.63
T ₁₂	34384	89685	55301	2.61