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Maximizing Nutrient Efficiency and Profitability: Integrating NADEP Compost and Phosphorous Solubilizing Bacteria in Black Gram (*Vigna mungo.* L) Cultivation

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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

Chemical fertilizers primarily focus on providing a few essential nutrients such as nitrogen, phosphorus, and potassium (NPK), neglecting other micronutrients required for healthy plant growth. This imbalance can lead to nutrient deficiencies in plants and subsequently in the food produced. Contributing to better food security and improved nutrition for the growing population, these organic manures and biofertilizers provide essential nutrients to the plants, improving their nutrient content and overall nutritional quality, which are highly valuable for addressing the

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nutritional needs of a growing population. Contrarily, imbalanced nutrition decreases productivity and deteriorates soil fertility, inturn increases the cost of cultivation. This problem can be only solved by quantifying biofertilizer integration with organic nutrients. With this in mind, an experiment was conducted in 2021 at the crop research center of the ITM University's School of Agriculture in Gwalior, Madhya Pradesh. Using a randomized block design with three replications of three different organic manures and bio-fertilizers. There are ten distinct treatments (from T1 to T10). Different types of organic manures and biofertilizers had a substantial impact on nutrition intake. The highest nutrient uptake (N, P, K, and Zn) was achieved when NADEP-2 t/ha + PSB-2.5 lit/ha (T_7) was applied in a manner comparable to the absolute control, that is, without the treatment of organic manures and biofertilizer. Furthermore, economics of different treatment, the maximum gross returns (Rs 1,48,995 ha^{-1}), net returns (Rs 1,11,335 ha^{-1}) and B:C ratio (2.95) was recorded under treatment T_7 for Urd bean.

Keywords: Organic manures; bio-fertilizers; nutrient uptake; economics; black gram; food security; soil fertility; chemical fertilizers; vermicompost.

1. INTRODUCTION

Pulses, which usually go by the moniker "poor man's protein source" due to their 20–25% protein content, are one of the key components of a vegetarian diet around the world [1-3]. Additionally, they offer environmental services to maintain soil health. Global pulse production increased at a 1.3% annual pace from the close of the 20th century to the first decade of the 21st [4] (Statista, 2020). Researchers [2,5] (Dhivya et al., 2020) estimated that pulses make up around 65% of the output of major pulses worldwide. The demand for pulses has been gradually rising over the past few years, resulting in a discrepancy between supply and demand. A growing population could result in increased consumption, which would widen this imbalance. By 2050, India, the world's second most populated nation, will need about 39 Mt of total pulses, which will require an annual growth rate of 2.2% (Statista, 2022). India is the leading producer of Black gram, scientifically known as *Vigna mungo L.,* belongs to the Fabaceae family. In 2021, India produced around 2.45 million tonnes of Urd from approximately 4.6 million hectares of cultivated land. The average productivity of black gram was recorded at 533 kilograms per hectare (source: agricoop.nic.in). This crop occupies around 19% of the total pulse acreage in India and contributes about 23% to the overall pulse production in the country [6].

Over the past century, chemical fertilizers have been extensively utilized for growing black gram throughout India. However, it has become evident that relying solely on fertilizers cannot sustain land productivity in modern farming practices because of high cost of cultivation. Excessive and prolonged use of chemical fertilizers has led to soil degradation, decreased productivity, negative environmental impacts and nutrient imbalance (Yadav and Lourd raj, 2005; Varsha et al., 2021). To ensure agricultural sustainability, economical stability and nutritional safety without compromising productivity, it is crucial to adopt practices that promote efficient plant nutrition management and conservation of natural resources.

Organic manures like vermicompost, NADEP compost, farmyard manure in addition to providing macronutrients, also satisfies the need for micronutrients while enhancing soil health and Selective strains of helpful soil microorganisms are cultivated in a lab and packaged in the right carrier to form biofertilizers. Through their activities in the soil or rhizosphere, they assist in generating critical nutrients for plants that have been solubilized, such as nitrogen and phosphorus, and gradually make them available to plants (Rajasekaran Murugan et al., 2011; Prajapati, 2014). According to Rajkhowa, et al., 2003; Gull et al., [7] that phosphorus solubilizing bacteria (PSB) play a crucial role in converting chemically fixed insoluble phosphate into a form that plants can readily utilize. This conversion process leads to increased crop yields. Similarly, potassium and zinc solubilizing bacteria are responsible for mobilizing potassium and zinc in the soil, thereby promoting higher yields in black gram crops.The utilization of organic materials is essential for preserving soil health. These organic substances contribute to the development of beneficial bacteria and the accumulation of organic matter in the soil. This, in turn, has numerous benefits. Organic fertilizers contain a diverse microbial load and growth-promoting chemicals, which, alongside the nutrient content, effectively enhance plant growth, metabolic activity, and resistance to pests and diseases (Shukla et al., 2015) [8]. To ensure long-term nutritional security for the growing population and to reduce cost of cultivation of black gram crop there is an urgent need to adopt integrated combination of organic manures and biofertilizers.

2. MATERIALS AND METHODS

The study titled "Impact of Organic Manures and Biofertilizers on Nutrient Uptake and Economic Returns in Black Gram (*Vigna mungo* L.) Cultivation" was carried out at the Crop Research Centre, School of Agriculture, ITM University in Gwalior, Madhya Pradesh, India. The research was conducted during the kharif season of 2021. The experimental site chosen for the study had specific climatic conditions suitable for black gram cultivation. In this research, various materials such as organic manures and biofertilizers were utilized. The procedures and techniques employed during the experiment were carefully implemented to ensure accurate and reliable results. The study aimed to assess the impact of these organic inputs on nutrient uptake and economic returns in black gram cultivation. The research farm is situated 206 meters above mean sea level with a latitude of 26°14°N and a longitude of 78°14°E. The soil texture of the experimental field was sandy clay loam in nature. Prior to sowing, a composite sample was made by merging several surface soil samples that were randomly collected up to 15 cm in depth and analyzed. It possessed modest concentrations of potassium (238.4 kg/ha), nitrogen (67 kg/ha), phosphorus (14.5 kg/ha), and organic carbon (0.12%). The experimental field was prepared after the start of the monsoon by a tractor-drawn disc plough (twice), then planked to get the desired tilth for proper germination and development of a plant stand. The land was cleared of weeds, grasses, and crop stubbles. The experiment was set up in a Randomized Block design and was repeated three times with three different types of organic manures in conjunction with biofertilizers. As a result, nine treatment combinations are possible The treatments are: T_1: 2 tons/ha of vermicompost + 2.5 liters/ha of phosphorus solubilizing bacteria (PSB) T_2: 2 tons/ha of vermicompost + 2.5 liters/ha of potassium solubilizing ;bacteria (KSB);T_3: 2 tons/ha of vermicompost + 2.5 liters/ha of zinc solubilizing bacteria (ZSB)T_4: 4 tons/ha of farmyard manure (FYM) + 2.5 liters/ha of PSB;T_5: 4 tons/ha of FYM + 2.5 liters/ha of KSB;T_6: 4 tons/ha of FYM + 2.5 liters/ha of ZSB;T_7: 2 tons/ha of NADEP compost + 2.5 liters/ha of PSB;T_8: 2 tons/ha of NADEP compost + 2.5 liters/ha of KSB;T_9: 2 tons/ha of NADEP compost + 2.5 liters/ha of ZSB;T_{10}: Complete control (no additional inputs used). For better soil incorporation, a weighed quantity of combined organic manures and bio-fertilizers was applied to the experimental plot two weeks prior to planting). For the control of insect pests like the white fly and pod-borer, neem oil (5%) and botanicals like datura leaf extract and ipomea leaf extract were applied. As soon as preliminary insect signs were noticed, all three sprays were applied. The crop was harvested when it had reached physiological maturity. The crop was threshed after it had been properly dried by the sun, and Gomez and Gomez's statistical approach was used to calculate and examine the statistics.

3. RESULTS AND DISCUSSION

The results obtained from the present investigation have been presented under following heads:

3.1 Nutrition Uptake Contributed by the Combined Effect of Organic Manures and Biofertilizers

3.1.1 Nitrogen uptake

The highest nitrogen uptake was recorded under the application of NADEP compost –2t/ha + PSB - 2.5l/ ha (T_7) by registering 2.5 kg/ha which is on par with the application of VC - 2t/ha + phosphorous solubilizing bacteria – 2.5l/ha (T_1) 2.48 kg/ha , with the application of NADEP - 2t/ha + ZSB - 2.5l/ha (T_9) 2.44 kg/ha and with application of FYM – 4t/ha + PSB – 2.5l/ha (T_4) 2.42 ka/ha. The least nitrogen uptake was recorded in the absolute control (T_{10}) with 2.07 kg/ha which was significantly inferior over the rest of the treatments.

3.1.2 Phosphorous uptake

The highest phosphorous uptake was recorded under the application of NADEP compost – 2t/ha + PSB - 2.5l/ ha (T_7) by registering 1.41 kg/ha which is on par with the application of VC - 2t/ha +phosphorous solubilizing bacteria – 2.5l/ha (T_1) 1.37 kg/ha, with application of NADEP - 2t/ha + ZSB -2.5l/ha (T_9) 1.34 kg/ha and with application of FYM – 4t/ha + PSB – 2.5l/ha (T_4) 1.32 kg/ha. The least phosphorous uptake was recorded in the absolute control (T_{10}) with 1.05 kg/ha which was significantly inferior over the rest of the treatments.

3.1.3 Potassium uptake

The highest potassium uptake was recorded under the application of NADEP compost – 2t/ha + PSB - 2.5l/ ha (T_7) by registering 3.05 kg/ha which is on par with the application of VC - 2t/ha +phosphorous solubilizing bacteria – 2.5l/ha (T_1) 2.97 kg/ha , with application of NADEP - 2t/ha + ZSB -2.5l/ha (T_9) 2.92 kg/ha and with application of FYM – 4t/ha + PSB – 2.5l/ha (T_4) 2.81 kg/ha The least potassium uptake was recorded in the absolute control (T_{10}) with 2.57 kg/ha which was significantly inferior over the rest of the treatments.

3.1.4 Zinc uptake

The highest Zinc uptake was recorded under the application of NADEP compost –2t/ha + PSB - 2.5l/ ha (T_7) by registering 0.49 kg/ha which is on par with the application of VC - 2t/ha + phosphorous solubilizing bacteria – 2.5l/ha (T_1) 0.48 kg/ha, with application of NADEP -2t/ha + ZSB -2.5l/ha (T9) 0.45 kg/ha and with application of FYM – 4t/ha + PSB – 2.5l/ha (T_4) 0.47 kg/ha. The least Zinc uptake was recorded in the absolute control (T_{10}) with 0.29 kg/ha which was significantly inferior over the rest of the treatments.

The maximum nutrition uptake was recorded in T_7 with Nitrogen (2.50 kg/ha), Phosphorus (1.41 kg/ha), Zinc (0.49 kg/ha)and Potassium (3.05 kg/ha) with application of NADEP- 2t/ha + PSB2.5lit/ ha where minimum nutrition uptake was observed in the control plot where Nitrogen (2.07 kg/ha) Phosphorus (1.05 kg/ha) Zinc (0.29 kg/ha) Potassium (2.57 kg/ha) So by the combined application of organic manures and biofertilizers rate of nutrition uptake increases The integration of NADEP compost with PSB biofertilizer has resulted in a significant increase in nutrient uptake at a lower cost, although the effects may last for a longer duration. PSB biofertilizers play a role in solubilizing insoluble or fixed phosphorus, making it easily available to plants in an ionic form that can be readily absorbed for metabolic processes. These findings align with the research conducted by Chakrabarti et al., [9], Kumpawat (2010), Patil et al., (2010), Mehta et al. [10], and Valetti et al., [11].

3.2 Influence of the Combined Application of Organic Manures and Bio-fertilizers on Black Gram Yield

3.2.1 Grain yield

The highest grain yield of 2128.50 kg/ha was observed when NADEP compost was applied at a rate of 2 t/ha along with PSB (phosphorus-solubilizing bacteria) at 2.5 lit/ha (T_7). Following closely was the treatment with VC (vermicompost) at 2 t/ha along with PSB at 2.5 lit/ha (T_1) that resulted in a grain yield of 2043.36 kg/ha. In comparison, the absolute control (T_{10}) had the lowest grain yield of 1520 kg/ha, which was significantly lower than the other treatments. The improved grain yield can be attributed to the increased availability of nitrogen and phosphorus in the soil, which leads to enhanced growth, development, and ultimately, higher yield (Tagore et al., 2013) [12].

Table 1. Effect of organic manures and biofertilizers on the nutrient uptake by black gram (kg/ha)

T. No	Treatment	N uptake (Kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)	Zn uptake (kg/ha)
T_1	VC + PSB	2.48	1.37	2.97	0.48
T_2	VC + KSB	2.4	1.31	2.79	0.42
T_3	VC + ZSB	2.38	1.29	2.77	0.39
T_4	FYM + PSB	2.42	1.32	2.81	0.47
T_5	FYM + KSB	2.24	1.16	2.67	0.4
T_6	FYM + ZSB	2.36	1.24	2.75	0.37
T_7	NADEP + PSB	2.5	1.41	3.05	0.49
T_8	NADEP + KSB	2.29	1.17	2.73	0.35
T_9	NADEP + ZSB	2.44	1.34	2.92	0.45
T_{10}	CONTROL	2.07	1.05	2.57	0.29
	SEm +/-	0.02	0.02	0.03	0.007
	CD @ 5%	0.07	0.05	0.10	0.02

3.2.2 Stover yield

The highest amount of stover was obtained when vermicompost was applied at 2 t/ha along with PSB at 2.5 lit/ha (T_1), resulting in 2860.7 kg, which was statistically equivalent to the application of NADEP compost at 2 t/ha along with zinc solubilizing bacteria (ZSB) at 2.5 lit/ha (T_9). The absolute control (T_{10}) showed the lowest stover yield of 1520.64 kg, significantly lower than the other treatments.

3.2.3 Biological yield

The biological yield per hectare was significantly influenced by the different levels of organic and bio-fertilizers. The application of VC at 2 t/ha along with PSB at 2.5 lit/ha (T_1) resulted in a higher biological yield of 4904.06 kg/ha, although this was comparable to NADEP compost at 2 t/ha along with PSB at 2.5 lit/ha (T_7) (4682.70 kg/ha) and NADEP compost at 2 t/ha along with ZSB at 2.5 lit/ha (T_9) (4628.70 kg/ha). The absolute control (T10) had the lowest biological yield of 2026.88 kg/ha, which was much lower than the other treatments. It was observed that the application of vermicompost and PSB resulted in vigorous growth but did not significantly impact yield, which aligns with the findings of Amit et al., 2021.

3.2.4 Harvesting index

The treatment with NADEP compost at 2 t/ha along with phosphorus-solubilizing bacteria (PSB) at 2.5 lit/ha (T_7) exhibited the highest harvest index of 45.45. In contrast, the absolute control (T_{10}) had the lowest harvest index of 25.05, significantly lower than the rest of the treatments. These findings are consistent with the results of Kumawat et al., [13], which indicated for generations, NADEP compost and PSB have been regarded as beneficial soil amendments. Most people realize that composting is an excellent approach to enhance healthy plant production, reduce cash and minimize the consumption of chemical fertilizers, and safeguard natural resources. Compost is a stable organic substance that improves the chemical, biological, and physical properties of soils, consequently improving nutritional and soil quality, crop yield, and agricultural productivity over time.

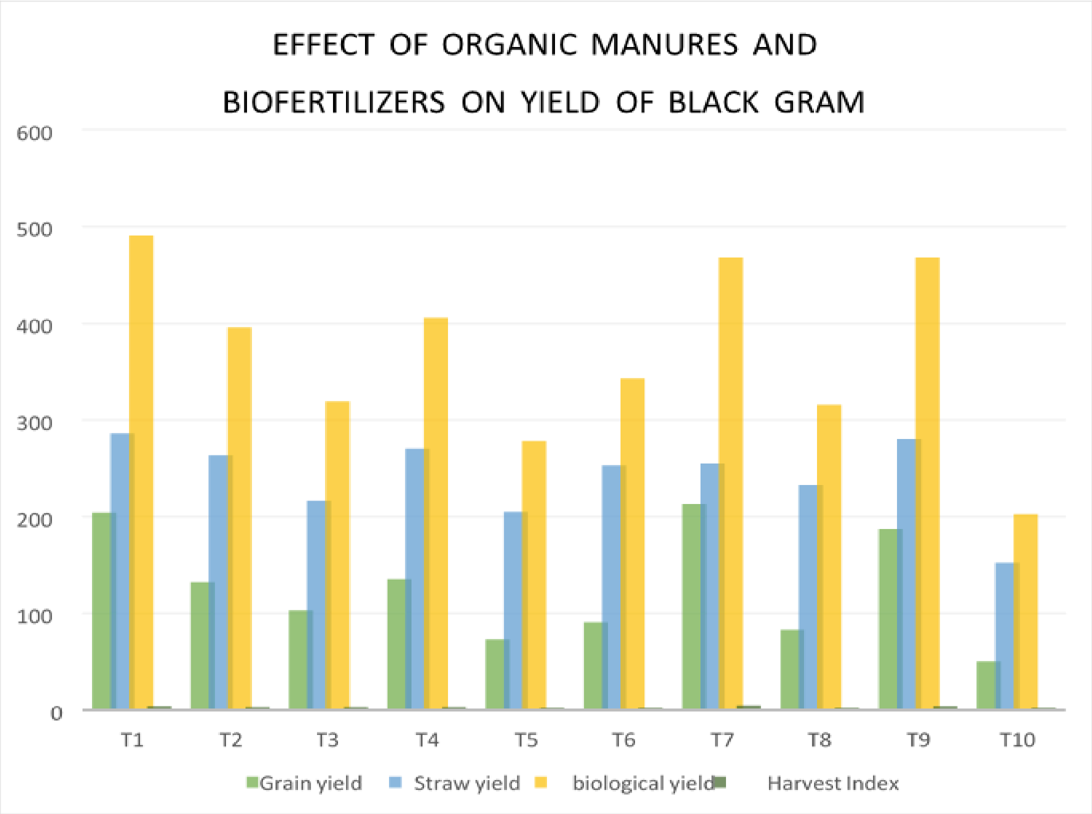

Fig. 1. Yield of green gram as influenced by combined application of organic manures and biofertilizers

Table 2. Effect of organic manures and biofertilizers on economics of black gram

T. No	Treatment	Cost of cultivation (Rs/ha)	Gross return (Rs/ha)	Net return (Rs/ha)	Benefit: Cost Rs/Rupee invested
T_1	VC + PSB	38,660	143,035.2	1,04,375	2.69
T_2	VC + KSB	38,660	92,400	53,740	1.39
T_3	VC + ZSB	38,660	72,072	33,412	0.86
T_4	FYM + PSB	37,660	94,710	57,050	1.51
T_5	FYM + KSB	37,660	51,282	13,622	0.36
T_6	FYM + ZSB	37,660	63,201.6	25,541.6	0.67
T_7	NADEP + PSB	37,660	1,48,995	1,11,335	2.95
T_8	NADEP + KSB	37,660	58,119.6	20,459.6	0.54
T_9	NADEP + ZSB	37,660	1,31,115.6	93,455.6	2.48
T_{10}	CONTROL	27,160	35,481.6	8,321.6	0.30

FYM = Manure from Farmyard, VC = Compost by earthworms, NADEP = Compost of NADEP, ZSB= Zinc Solubilizing Bacteria, PSB = Phosphorous Solubilizing Bacteria, KSB = Potassium Solubilizing Bacteria.

3.3 Combined Effect of Organic Manures and Biofertilizers on the Economics of Black Gram

Higher economic return is an important consideration in the selection of nutrient management practices. Farmers are mostly concerned with a high return per unit area, time and investment. The economics of black gram cultivation were worked out by calculating the cost of cultivation item-wise and deducting it from price of products to get net return. Application of different nutrients increased the cost of cultivation while reducing the cost of production due to an increase in the yield. The highest cost of cultivation was obtained under the application of VC - 2t/ha + phosphorous solubilizing bacteria – 2.5l/ha (T_1) found significantly superior over other treatments and closely followed by the application of NADEP compost - 2t/ha + PSB - 2.5l/ha (T_7) Whereas lowest Net monetary return was noted with absolute control (T_{10}).There was significant increase in grain yield due to application of different organic manures and biofertilizers thereby resulting in significant increase in gross return as well as in net return. However, the maximum gross return and net return were recorded in the application of NADEP compost - 2t/ha + PSB - 2.5l/ha (T_7) found significantly superior over other treatments and closely followed by the application of VC - 2t/ha + phosphorous solubilizing bacteria – 2.5l/ha (T_1), NADEP compost - 2t/ha + ZSB – 2.5l/ha (T_9), FYM – 2t/ha+ PSB- 2.5l/ha (T_4). Whereas lowest was noted with without application of organic manures and bio fertilizer (Control, T_{10}). The results confirm to the research findings of Bahadur et al. [14]; Kumawat et al., [13]; Dwivedi et al.,[15]; Nallagatla et al., [16]; & Rabari et al., [17], [18-25].

4. CONCLUSION

This research conducted at the crop research center, School of Agriculture, ITM University, Gwalior, aimed to address the limitations of chemical fertilizers by examining the impact of organic manures and biofertilizers on nutrient uptake, economics, and crop productivity. The findings clearly demonstrate that the integration of organic manures and biofertilizers significantly influenced the nutrition uptake of black gram plants. Among the ten treatments tested, the application of NADEP- 2 t/ ha + PSB- 2.5 lit/ ha (T7) resulted in the highest nutrient uptake, including nitrogen, phosphorus, potassium, and zinc. This indicates the effectiveness of combining organic manures and biofertilizers in improving the nutrient content and overall nutritional quality of the crops. Furthermore, the economic analysis revealed that treatment T7 also yielded the maximum gross returns, net returns, and a favorable benefit-cost ratio for Urd bean cultivation. Integrating organic manures and biofertilizers significantly improved nutrient uptake and economic returns in black gram cultivation. This highlights the importance of adopting these practices for sustainable and nutrient-rich food production, addressing imbalanced nutrition, and promoting soil health for better food security and nutrition but also offers economic benefits to farmers.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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