International Journal of Environment and Climate Change

Volume 13, Issue 11, Page 4466-4471, 2023; Article no.IJECC.110453
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Influence of Soil and Foliar Application of Nutrients on Growth and Yield of 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.

Article Information

DOI: 10.9734/IJECC/2023/v13i113626

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/110453

Original Research Article

Received: 25/09/2023
Accepted: 02/12/2023
Published: 07/12/2023

ABSTRACT

Aims: This study aims to scrutinize the intricacies of nutrient management to optimize the cultivation of black gram (*Vigna mungo* L.) during the *Rabi* season of 2022-2023 in Coimbatore. The primary objectives include evaluating the efficacy of various treatments, such as recommended doses of inorganic fertilizer (RDF), rhizobium, and Phosphobacteria microbial inoculants as soil applicants, as well as TNAU Pulse Wonder, nano urea, and DAP as foliar sprays.
Study Design: A meticulous Randomized Block Design (RBD) with three replications was employed to explore diverse treatments. This design allowed for a systematic investigation into the impact of different nutrient management strategies on the growth and yield of black grams.

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Place and Duration of Study: The study was conducted in Coimbatore, and the Rabi season of 2022-2023 was chosen for its duration. The experimental setup was established at the research farm under the auspices of the Karunya Institute of Technology and Sciences.

Methodology: A total of ten treatments were tested, including various combinations of RDF (25:50:25), rhizobial culture, phosphobacteria, TNAU Pulse Wonder, nano urea, and DAP. Plant growth metrics, such as plant height and leaf count, were measured at 60 days after sowing (DAS). Yield attributes, including pod count, seeds per pod, and test weight, were also evaluated. Economic scrutiny included the calculation of the cost of cultivation, gross return, net income, and benefit-cost ratio.

Results: Treatment T_7, consisting of 75% RDF, rhizobial culture, phosphobacteria, and 1% TNAU Pulse Wonder, demonstrated substantial efficacy in enhancing plant growth metrics. At 60 DAS, this treatment exhibited an appreciable increase in plant height (39.89 cm) and leaf count (15.33). Moreover, T_7 positively impacted crucial yield attributes, with elevated pod count (24.33), seeds per pod (9.33), and test weight (4.98 g). Economic scrutiny identified T_7 as the epitome of economic viability, featuring a cost of cultivation at 30,240 INR, gross return of 125,587.80 INR, net income of 95,347.80 INR, and a commendable benefit-cost ratio of 4.15.

Conclusion: These findings underscore the profound significance of strategic nutrient management paradigms for fostering sustainable and economically robust black gram cultivation. The identified treatment T7 stands out as a promising approach to optimize yields and economic returns in black gram cultivation, offering valuable insights for future agricultural practices.

Keywords: Black gram; nutrient management; plant growth; yield attributes; economic viability; rabi season; TNAU pulse wonder; T_7 treatment; B:C ratio.

1. INTRODUCTION

Pulses, comprising a vital group within the Fabaceae family, are integral to global agriculture [1]. In the Indian subcontinent, staple pulses like chickpeas, pigeon peas, green gram, black gram, kidney beans, and field peas hold cultural, nutritional, and economic significance. These annual leguminous plants, characterized by their pod-bearing nature, contribute significantly to both feed and food production. Recognized for their high protein content and low glycaemic index, pulses play a crucial role in staple diets, particularly in developing regions like South Asia and Africa, where they help address Protein Calorie Malnutrition (PCM), particularly in infants, young children, and nursing mothers [2]. According to the Food and Agricultural Organization [3] statistics for 2021, leguminous crops cover a substantial 93.54 million hectares globally, generating a total production of approximately 92.13 million tons, with a productivity rate reaching 985 kg per hectare. In India alone, pulses are cultivated over approximately 287.83 lakh hectares of land, producing 254.63 lakh tonnes annually at a productivity rate of 885 kg ha^{-1} [4]. Tamil Nadu, a prominent agricultural state, contributes to this pulse cultivation, with a land expanse of 8.03 lakh hectares, yielding a total production of 4.72 lakh tonnes and achieving a productivity rate of 588 kg per hectare. Black gram (*Vigna mungo* L.) cultivation, renowned for its nutritional value and adaptability, faces challenges demanding comprehensive research for sustainable and efficient production. Nutrient management emerges as a critical issue [5,6]. Rich in phosphoric acid, proteins, carbohydrates, and calcium, black gram occupies a significant place in Indian agriculture. India, being the largest global producer of pulses, contributes over 70% of the world's black gram production. Major black gram-producing states include Madhya Pradesh, Uttar Pradesh, Punjab, Maharashtra, West Bengal, Andhra Pradesh, Orissa, Tamil Nadu, and Karnataka. Within the pulse crop category, black gram commands approximately 19% of the total pulse cultivation area in India, contributing to 23% of the overall pulse food production and this pulse occupies about 41.43 lakh hectares of land in India, yielding approximately 22.30 lakh tonnes of food annually at a productivity rate of 591 kg ha^{-1} [4]. However, despite its nutritional prowess, the yield of black gram has faced challenges in recent years. Factors contributing to this decline include a decrease in nutrient use efficiency, uneven application of chemical fertilizers, and the high cost of these fertilizers preventing farmers from applying them at recommended levels. The indiscriminate use of chemical inputs has not only reduced crop productivity but also led to soil degradation, necessitating the exploration of alternative sustainable production system [7]. The objectives of the study include optimizing black gram yields through different nutrient management strategies, studying the impact of various nutrient management practices on the growth and yield of black gram, and evaluating the economics of black gram under different nutrient management practices. This research aspires to provide insights that contribute to sustainable agricultural practices and the overall well-being of farming communities.

2. MATERIALS AND METHODS

2.1 Study Area Location

The study was conducted in the instructional farm of the School of Agricultural Sciences, Karunya Institute of Technology and Science, Coimbatore, during the *Rabi* season of 2022-2023. The geographical coordinates of the experimental site are approximately 10°56'N latitude and 76°44'E longitude, situated at an altitude of 474 meters above mean sea level. The choice of this location was made to represent the Northwestern Agroclimatic Zone of Tamil Nadu, providing a suitable environment for the cultivation of the selected crop. The monsoon season typically commences in late June and extends through September. Over the specified period, a total precipitation of 326.6 millimetres was recorded. The average high temperature stood at 31.12 degrees Celsius, with an average low of 23.56 degrees Celsius. The mean maximum relative humidity was 76.35%, while the minimum relative humidity averaged at 53.49%.

2.2 Experimental Details

The research was conducted using a Randomized Block Design (RBD) to ensure the robustness of the experimental setup, and each treatment was replicated three times to enhance the reliability of the results. The chosen crop was black gram Variety Vamban-8. The experimental plots were designated with a gross size of 4m x 3m and a net size of 3.5m x 2.1m, adhering to a seed rate of 20 kg ha^{-1} and a spacing of 30cm x 10cm. The study focused on investigating the influence of various soil and foliar nutrient management approaches on black gram cultivation. The treatments employed in the field experiments were T_1 - Recommended Dose Fertilizer (RDF) @ 25:50:25 kg of N, P_2O_5, and K_2O ha^{-1} as a basal dose, T_2 - RDF + Foliar spray of 1% (5 kg ha^{-1} in 500 litres of water) TNAU Pulse wonder , T_3 - RDF + Foliar spray of 1% urea at 30 and 45 days after sowing (DAS), T_4 - RDF + Foliar spray of Nano urea@ 2 ml $litre^{-1}$ at 30 and 45 DAS, T_5 - RDF + Foliar spray of 2% DAP at 30 and 45 DAS with, T_6 - 75% RDF + Soil application of Rhizobium and Phosphobacteria @ 2 kg ha^{-1}, T_7 - 75% RDF + Soil application of Rhizobium and Phosphobacteria @ 2 kg ha^{-1} + Foliar spray of 1% TNAU Pulse wonder at 30 and 45 DAS, T_8 - 75 % RDF + Soil application of Rhizobium and Phosphobacteria @ 2 kg ha^{-1} + Foliar spray of 1% urea at 30 and 45 DAS, T_9 - 75 % RDF + Soil application of Rhizobium and Phosphobacteria @ 2 kg ha^{-1} + Foliar spray of Nano urea @ 2ml $litre^{-1}$ of water at 30 and 45 DAS T_{10} - 75 % RDF + Soil application of 2 kg each of Rhizobium culture and Phosphobacteria @ 2 kg ha^{-1} + Foliar spray of 2% DAP @ 30 and 45 DAS. All the treatments received a uniform and meticulous management practices such as field preparation, weed management and irrigation. The selection of treatments aimed to explore the synergies of different nutrient combinations and their impact on black gram physiology and yield.

2.3 Nutrient Application

In the field experiments, a comprehensive set of nutrient application treatments was implemented. The first treatment (T_1) involved the application of the recommended basal dose (RDF), consisting of 25:50:25 kg of Nitrogen (N), Phosphorus (P_2O_5), and Potassium (K_2O) per hectare. The second treatment (T_2) augmented the Recommended Dose Fertilizer (RDF) with a foliar spray of 1% TNAU Pulse Wonder, applied at a rate of 5 kg ha^{-1} in 500 litres of water. Treatment T_3 incorporated the basal dose of RDF, accompanied by foliar spray applications of 1% urea at 30 and 45 days after sowing (DAS). Additionally, treatment (T_4) involved the basal dose of RDF, supplemented with foliar spray applications of Nano urea at 2 ml $litre^{-1}$ at 30 and 45 DAS. Treatment (T_5) included the basal dose of RDF, with foliar spray applications of 2% Diammonium Phosphate (DAP) at 30 and 45 DAS. Further variations were introduced with treatments T_6 to T_{10}, all incorporating 75% of the recommended dose of fertilizer. These treatments included soil applications of Rhizobium and Phosphobacteria at 2 kg ha^{-1}, with additional foliar sprays of 1% TNAU Pulse Wonder, 1% urea, Nano urea, or 2% DAP at specific intervals. The meticulous design of these treatments aimed to facilitate a detailed examination of the interactions between different nutrient management approaches and their impact on the growth and yield of black gram.

2.4 Statistical Analysis

Fisher's method of analysis of variance (ANOVA) was used to statistically analyse the experimental data acquired, according to Gomez & Gomez [8]. Critical Difference (CD) values were calculated wherever the 'F' test was found significant at 5 percent level.

3. RESULTS AND DISCUSSION

3.1 Optimizing the Crop Growth Attributes of Black Gram through Soil and Foliar Nutrient Management Practices

The data on plant growth parameters of black gram recorded at 20 DAS, 40 DAS, and 60 DAS are presented in Table 1. On 20 DAS among the various nutrient management practices studied, there was no significant difference in any of the growth parameters recorded, but there was a significant difference among the treatments were observed at 40 DAS and 60 DAS. The treatment, T_7 registered a superior growth parameter among all the treatments, with an increased plant height of 29.80 cm at 40 DAS, and 39.89 cm at 60 DAS, a higher mean leaf count of 8.67 at 40 DAS and 15.33 at 60 DAS and a greater dry matter production of 1210.46 kg ha^{-1} at 40 DAS and 2685.43 kg ha^{-1} at 60 DAS. This significant increase in plant height, number of leaves per plant and dry matter production under the treatment T_7, with 75% RDF, soil-applied rhizobium and Phosphobacteria, and foliar spray of TNAU pulse wonder, might be attributed to the enhanced synergistic effects influenced by the substantial contribution of micronutrient-rich TNAU pulse wonder in combination with the applied soil applied 75% RDF and the microbial culture in the form of biofertilizers. This combined effects of soil and foliar applied nutrients might have triggered the plant growth vigour through enhanced physiological processes and improved photosynthetic efficiencies of the crop. This conforms with the findings of Sachin et al. [9] and Balaji et al. [10].

3.2 Enhancing the Yield Attributes and Yield of Black Gram through Soil and Foliar Nutrient Management Practices

The data on yield attributes and yield of black gram are presented in Table 2. Among all the treatments, the treatment T_7, (75% RDF, soil applied Rhizobium and Phosphobacteria, and a foliar spray of TNAU pulse wonder at 30 and 45 DAS), registered a significantly higher pod count per plant (24.33), seeds per pod (9.33), test weight (4.98 g) and eventually the higher grain yield (1073.4 kg ha^{-1}) and stover yield (1612.03 kg ha^{-1}). The significant increase in the grain yield under the treatment T_7 could be attributed to the better nutrient availability for the crop during its growth stages and could have had an enhanced source-sink relationship leading to better grain filling and development. This would have eventually resulted in better yield attributes and finally impacted a higher grain and stover yield. This is in line with the findings of Kumaran et al. [11].

Table 1. Effect of nutrient management on growth parameter in black gram

Treatment	Plant Height (cm)			No of Leaves			Dry Matter Production		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
T_1	16.5	20.1	26.5	3	5.33	7.03	269.74	607.4	1705.74
T_2	17.63	23.6	31.58	3	6.33	10	290.45	811.42	2045.86
T_3	16.82	23.1	31.02	3	6	9.33	280.44	792.44	2006.63
T_4	17.27	23.4	31.03	2.67	6	9.67	280.64	798.5	2019.67
T_5	17.49	23.5	31.3	2.67	6.33	9.67	285.46	815.74	2030.52
T_6	16.8	20.3	27.36	3	5	7.15	279.33	623.16	1712.66
T_7	18.48	29.8	39.89	3	8.67	15.33	299.33	1210.46	2685.43
T_8	17.59	26.5	35.25	2.67	7.3	12.33	295.26	987.1	2336.94
T_9	18.46	27	36.21	3	7.67	12.67	295.46	1040.5	2396.32
T_{10}	17.35	26.6	35.45	2.67	7.67	12.67	295.41	1025.28	2364.41
Mean	17.44	24.39	32.56	2.87	6.63	10.59	287.15	871.2	2130.42
SE(d)	0.62	1.29	1.73	0.86	0.43	1.03	25.82	80.24	137.71
CD (5%)	NS	2.71	3.63	NS	0.9	2.17	NS	168.58	289.31

** T_1- RDF (25:50:25 kg of N, P_2O_5 & K_2O ha^{-1} applied as basal), T_2 - RDF + Foliar spray of 1% (5 kg ha^{-1} in 500 litres of water) TNAU Pulse wonder @ 5 kg ha^{-1} at 30 and 45 DAS, T_3 - RDF + Foliar spray of 1% urea at 30 and 45 DAS, T_4 - RDF + Foliar spray of Nano urea @ 2ml $litre^{-1}$ of water at 30and 45 DAS, T_5 - RDF + Foliar spray of 2% DAP @ 30 and 45 DAS, T_6 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria, T_7- 75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 1% TNAU Pulse wonder at 30and 45 DAS, T_8 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 1% urea at 30 and 45 DAS, T_9 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of Nano urea @ 2ml $litre^{-1}$ of water at 30 and 45 DAS, T_{10} -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 2% DAP @ 30 and 45 DAS*

Table 2. Effect of nutrient management on yield and yield attributes in black gram

Treatment	Pods per Plant	Seeds per Pod	100 Grain Weight (g)	Grain Yield (kg ha⁻¹)	Stover Yield (kg ha⁻¹)	Harvest Index
T_1	11.33	6	3.31	524.56	1011.18	0.34
T_2	16	7.67	4.03	771.3	1242.96	0.38
T_3	15.33	7.33	3.84	658.96	1216.67	0.35
T_4	15.33	7.33	3.98	661.66	1228.01	0.35
T_5	15.67	7.67	4	677.56	1238.06	0.35
T_6	11.67	6.33	3.45	531.53	1041.13	0.34
T_7	24.33	9.33	4.98	1073.4	1612.03	0.4
T_8	19.67	8.33	4.44	897.9	1416.99	0.39
T_9	20.67	8.67	4.6	946.71	1456.61	0.39
T_{10}	20.33	8.33	4.52	927.42	1429.04	0.39
Mean	17.03	7.7	4.12	767.1	1289.27	-
SE(d)	1.72	0.22	0.17	60.25	73.16	-
CD (5%)	3.62	0.45	0.36	126.57	153.7	-

** T_1- RDF (25:50:25 kg of N, P_2O_5 & K_2O ha^{-1} applied as basal), T_2 - RDF + Foliar spray of 1% (5 kg ha^{-1} in 500 litres of water) TNAU Pulse wonder @ 5 kg ha^{-1} at 30 and 45 DAS, T_3 - RDF + Foliar spray of 1% urea at 30 and 45 DAS, T_4 - RDF + Foliar spray of Nano urea @ 2ml $litre^{-1}$ of water at 30and 45 DAS, T_5 - RDF + Foliar spray of 2% DAP @ 30 and 45 DAS, T_6 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria, T_7- 75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 1% TNAU Pulse wonder at 30and 45 DAS, T_8 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 1% urea at 30 and 45 DAS, T_9 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of Nano urea @ 2ml $litre^{-1}$ of water at 30 and 45 DAS, T_{10} -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 2% DAP @ 30 and 45 DAS.*

Table 3. Effect of nutrient management on economic production of blackgram

Treatment	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net income (₹ ha^{-1})	B:C ratio (₹ ha^{-1})
T_1	31767.00	61373.52	29606.52	1.93
T_2	31341.00	90242.10	58901.10	2.88
T_3	28170.00	77098.32	48928.32	2.74
T_4	28290.00	77414.22	49124.22	2.74
T_5	28200.00	79274.52	51074.52	2.81
T_6	31341.00	62189.01	30848.01	1.98
T_7	30240.00	125587.80	95347.80	4.15
T_8	29220.00	105054.30	75834.30	3.60
T_9	29430.00	110765.07	81335.07	3.76
T_{10}	29340.00	108508.14	79168.14	3.70

** T_1- RDF (25:50:25 kg of N, P_2O_5 & K_2O ha^{-1} applied as basal), T_2 - RDF + Foliar spray of 1% (5 kg ha^{-1} in 500 litres of water) TNAU Pulse wonder @ 5 kg ha^{-1} at 30 and 45 DAS, T_3 - RDF + Foliar spray of 1% urea at 30 and 45 DAS, T_4 - RDF + Foliar spray of Nano urea @ 2ml $litre^{-1}$ of water at 30and 45 DAS, T_5 - RDF + Foliar spray of 2% DAP @ 30 and 45 DAS, T_6 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria, T_7- 75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 1% TNAU Pulse wonder at 30and 45 DAS, T_8 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 1% urea at 30 and 45 DAS, T_9 -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of Nano urea @ 2ml $litre^{-1}$ of water at 30 and 45 DAS, T_{10} -75 % RDF + Soil application of 2 kg each of Rhizobial culture and Phosphobacteria + Foliar spray of 2% DAP @ 30 and 45 DAS.*

3.3 Evaluating the Economic Viability of Soil and Foliar Nutrient Management Practices in Black Gram Cultivation

The data on the economic viability of soil and foliar application of nutrients in black gram is presented below in Table 3. Among all the treatments, the treatment T_7 (75% RDF, soil applied Rhizobium and Phosphobacteria, and a foliar spray of TNAU pulse wonder at 30 and 45 DAS), emerged as the most economically efficient practice, boasting a cost of cultivation at 30,240 INR, a gross return of 1,25,587.80 INR, net income of 95,347.80 INR, and a commendable B: C ratio of 4.15. The superior economic performance of this treatment can be attributed to their higher grain yield, coupled with a 25% reduction in inorganic fertilizer application, resulting in lower production costs. These outcomes substantiate the studies by Anil et al. [12] and Gayethri et al. [13], underscoring the pivotal role of strategic nutrient management in enhancing the economic sustainability of black gram cultivation.

4. CONCLUSION

Based on the results of the experiment it can be concluded that the soil and foliar application of nutrients in the form of 75% of recommended dose of fertilizer along with soil-applied Rhizobium and Phosphobacteria, and a foliar spray of TNAU pulse wonder at 30 and 45 DAS proves to be beneficial and advantageous in terms of, grain yield and returns per rupee invested, rather than going for the blanket application of recommended dose of fertilizer.

On the other hand, reducing the application of recommended inorganic fertilizers by 25% serves as an environmentally sustainable nutrient management measure while also improving the yield of black gram.

ACKNOWLEDGEMENT

The authors are grateful to the Division of Agronomy, School of Agricultural Sciences (SAS), Karunya Institute of Technology and Sciences (KITS), Coimbatore, Tamil Nadu – 641114.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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