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Biochar and Organic Amendments in Integrated Nutrient Management: Effects on Growth, Yield and Seed Quality of Blackgram (*Vigna mungo* (L.) Hepper)

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Authors' contributions

This work was carried out in collaboration between both authors. Author JL conducted the experimental work and prepared the manuscript. Author PKS supervised the research and contributed to data interpretation and manuscript revision. Both authors read and approved the final manuscript.

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Abstract

Integrated nutrient management offers a potential approach to improving crop productivity and seed quality through the combined use of organic and inorganic nutrient sources. A field experiment was conducted during the kharif seasons of 2023 and 2024 at the Experimental Farm, Department of Soil Science, School of Agricultural Sciences, Nagaland University, Medziphema, Nagaland, India, to assess the effects of biochar-based integrated nutrient management on the growth, yield attributes and seed protein content of blackgram (*Vigna mungo* (L.) Hepper) cv. PU-31. The experiment comprised 18 nutrient management treatments arranged in a randomised block design with three replications. The treatments involved different combinations of recommended dose of fertiliser (RDF), biochar (BC), farmyard manure (FYM) and vermicompost (VC). Pooled results showed treatment effects on plant height, branch number, several yield attributes, seed yield, stover yield and seed protein content. Leaf chlorophyll readings differed significantly at harvest, but not at 50 DAS. The treatment comprising 50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}

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(T_{12}) recorded the highest plant heights of 18.91, 43.84 and 54.17 cm at 25 days after sowing (DAS), 50 DAS and harvest, respectively. It also recorded 4.61 and 5.43 branches plant^{-1} at 50 DAS and harvest, respectively, and the highest chlorophyll readings of 39.05 and 38.30 SPAD units at the corresponding stages. Among the yield attributes, T_{12} produced 36.46 pods plant^{-1} and 5.37 seeds pod^{-1}, with a 1,000-seed weight of 35.45 g. The highest pooled seed yield (634.87 kg ha^{-1}), stover yield (1324.51 kg ha^{-1}) and seed protein content (23.26%) were also recorded under T_{12}, representing increases of 55.58%, 49.65% and 5.68%, respectively, relative to the control. These results indicate that combining 50% RDF with biochar, FYM and vermicompost improved several growth and yield attributes, crop productivity and seed protein content under the conditions of the experiment.

Keywords: Biochar; blackgram; INM; vermicompost; FYM; seed protein.

1. Introduction

Blackgram (*Vigna mungo* (L.) Hepper), commonly known as urdbean, is an important short-duration pulse crop belonging to the family Fabaceae and is widely cultivated in India during the kharif and summer seasons. It is an important component of Indian agriculture and food systems owing to its high nutritional value. The seeds are rich in high-quality, easily digestible protein and also contain carbohydrates, fats, amino acids, vitamins and minerals such as calcium, iron and potassium. Blackgram is also valued for its versatility in cropping systems, where it can be grown as a sole, mixed, catch, cover or sequential crop (Bonepally *et al.*, 2021). As a leguminous crop, it contributes to soil fertility through biological nitrogen fixation and can therefore contribute to the nitrogen economy of subsequent crops. Despite its importance, the productivity of blackgram remains relatively low, particularly under conditions of marginal and less fertile soils, inadequate nutrient application, moisture stress, pest and disease incidence and limited adoption of improved production technologies. The availability of quality seed and short-duration varieties, along with improved crop and nutrient management practices, therefore offers considerable scope for enhancing productivity. Proper agronomic practices and balanced fertilisation are important for improving the growth, yield and nutrient acquisition of blackgram. Nutrient management is particularly important because continuous cultivation and inadequate nutrient replenishment can result in depletion of soil nutrients and deterioration of soil fertility. Although chemical fertilisers play an important role in meeting the nutrient requirements of crops, their sole and continuous use may not adequately maintain soil health. Therefore, greater emphasis has been placed on integrated nutrient management (INM), which combines inorganic fertilizers with organic sources to provide a more balanced and sustained supply of nutrients. Integrated nutrient management can improve nutrient availability, crop growth, productivity and nutrient uptake while also contributing to the maintenance of soil fertility. Studies on blackgram have demonstrated that the integration of recommended fertilizers with organic sources such as FYM and other nutrient inputs can improve productivity and nutrient acquisition (Behera and Mohapatra, 2022). Among organic nutrient sources, vermicompost has emerged as an effective amendment for sustainable crop production. It supplies nutrients in readily available forms and can improve soil structure, nutrient availability, microbial activity and enzymatic functions (Das *et al.*, 2019). The bio-oxidative process of vermicomposting, involving earthworms and microorganisms, accelerates organic matter decomposition and contributes to humus formation and nutrient solubility (Thakur *et al.*, 2021). In addition to conventional organic amendments, biochar has received considerable attention as a soil amendment because of its porous structure, high surface area and potential to improve nutrient retention and other soil properties. A recent meta-analysis highlighted that crop responses to biochar vary with soil characteristics and biochar properties, supporting the need for context-specific evaluation (Han *et al.*, 2023). Related studies have assessed organic nutrient sources in green gram under rainfed conditions (Rambuatsaiha *et al.*, 2017) and the application of biochar and vermicompost to tomato in relation to photosynthesis and yield (Liu *et al.*, 2022).

In wheat, the combined application of biochar, vermicompost and mineral fertilisers has been investigated for its effects on soil properties and crop productivity (Hasan *et al.*, 2024). Field research on soybean has also examined biochar, farmyard manure and vermicompost alongside reduced mineral fertiliser inputs as an integrated nutrient management approach (Bajpayi *et al.*, 2026).

Reviews have further described the potential of biochar in acidic soils (Okine *et al.*, 2026) and the variable effects of applying biochar with fertilisers on nutrient leaching and availability (Dissanayake *et al.*, 2026).

The experimental soil was strongly acidic (initial pH 4.43), making the evaluation of biochar relevant to local nutrient-management conditions. Biochar amendments may moderate soil acidity and influence nutrient availability in some acidic soils, but responses differ with amendment properties and soil characteristics. A meta-analysis of soil amendments in acidic soils reported context-dependent responses of soil pH and crop yield to biochar application (Zhang *et al.*, 2023). This evidence provides a rationale for evaluating bamboo biochar together with organic manures and mineral fertiliser at Medziphema, without presupposing that a particular soil-chemical change occurred in the present experiment.

Integrating biochar with organic manures and mineral fertilisers may complement nutrient supply and retention. Mineral fertilisers provide readily available nutrients, organic amendments release nutrients during decomposition, and biochar may help retain nutrients and reduce leaching under suitable soil conditions. However, the effectiveness of these amendments depends on their properties and the soil and climatic conditions. While the isolated merits of biochar and organic manures are well recognised, empirical field evidence evaluating their combined integration with reduced chemical fertilizer rates in blackgram remains limited. The response of blackgram yield and seed protein content to these combined inputs at reduced mineral fertiliser rates under the acidic soil conditions of Medziphema therefore warrants evaluation. Accordingly, the present study was undertaken to evaluate the effects of biochar-based integrated nutrient management involving mineral fertiliser, farmyard manure and vermicompost on the growth, yield attributes, seed yield, stover yield and seed protein content of blackgram under the agro-climatic conditions of Medziphema, Nagaland.

2. Materials and Methods

2.1 Experimental Site and Treatment

The field experiment was conducted during the *kharif* seasons of 2023 and 2024 at the Experimental Farm of the Department of Soil Science, School of Agricultural Sciences, Nagaland University, Medziphema, Nagaland, India. The experimental site was located at 25°45′30″ N latitude and 93°53′04″ E longitude, at an elevation of 310 m above mean sea level. The experiment was conducted on blackgram (*Vigna mungo* (L.) Hepper) cv. PU-31 in a randomised block design (RBD) comprising 18 treatments and three replications, resulting in 54 experimental plots. Each plot measured 2.1 × 2.0 m, with a spacing of 30 × 10 cm. The nutrient management treatments comprised different combinations of recommended dose of fertiliser (RDF), biochar (BC), farmyard manure (FYM) and vermicompost (VC): (1) Control; (2) 100% RDF; (3) BC at 2 t ha^{-1}; (4) BC at 4 t ha^{-1}; (5) FYM at 4 t ha^{-1}; (6) VC at 1.3 t ha^{-1}; (7) 50% RDF + BC at 2 t ha^{-1} + FYM at 2 t ha^{-1}; (8) 50% RDF + BC at 2 t ha^{-1} + VC at 0.6 t ha^{-1}; (9) 50% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}; (10) 50% RDF + BC at 4 t ha^{-1} + FYM at 2 t ha^{-1}; (11) 50% RDF + BC at 4 t ha^{-1} + VC at 0.6 t ha^{-1}; (12) 50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}; (13) 75% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1}; (14) 75% RDF + BC at 2 t ha^{-1} + VC at 0.3 t ha^{-1}; (15) 75% RDF + BC at 2 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}; (16) 75% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1}; (17) 75% RDF + BC at 4 t ha^{-1} + VC at 0.3 t ha^{-1}; and (18) 75% RDF + BC at 4 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}.

2.2 Land Preparation and Crop Management

The experimental field was prepared, levelled and laid out according to the experimental design. FYM was applied 30 days before sowing whereas bamboo biochar was applied and incorporated into the soil 15 days prior to sowing. Blackgram cv. PU-31 was line sown at a depth of approximately 1.5 cm. Thinning was carried out at 15 days after sowing (DAS) to maintain a spacing of 30 cm between rows and 10 cm between plants. Vermicompost and fertilisers were applied according to the respective treatments prior to sowing. Hand weeding was carried out as required during crop growth. Pods were harvested in four to five pickings. After the final picking, the crop was cut at ground level using a sickle. Harvested pods were sun-dried, threshed and cleaned manually.

2.3 Initial Soil Characteristics

The soil at the experimental site initially had a sandy clay loam texture, comprising 51.2% sand, 19.3% silt and 29.5% clay. The soil was acidic, with a pH of 4.43 and an electrical conductivity of 0.14 dS m^{-1}. The cation exchange capacity was 10.81 cmol(p^{+}) kg^{-1}, and the organic carbon content was 18.98 g kg^{-1}. The available nitrogen, phosphorus, potassium and sulphur contents were 213.87, 9.24, 159.60 and 10.15 kg ha^{-1}, respectively.

2.4 Biometrical Observations

Biometrical observations were recorded from five randomly selected and tagged plants per plot. Plant height was measured from ground level to the apex of the main shoot at 25 DAS, 50 DAS and harvest. The number of primary branches per plant was recorded at 50 DAS and at harvest, as no branches were observed at 25 DAS. Leaf chlorophyll index (SPAD) was estimated at 50 DAS and prior to harvest from the third fully expanded trifoliate leaf from the terminal bud using a calibrated chlorophyll meter. Yield attributes, including pods plant^{-1}, and seeds pod^{-1}, were documented from tagged plants at harvest. 1,000-seed weight was determined by weighing 1000 clean, sun-dried seeds sampled randomly from plot yields. Seed and stover yields were recorded on a net plot basis after post-harvest cleaning and moisture adjustment to ~10–12%, and were subsequently converted to kg ha^{-1}. Seed nitrogen content was determined using the micro-Kjeldahl digestion and distillation method. Crude protein content (%) was calculated by multiplying the seed nitrogen content (%) by the conversion factor of 6.25.

2.5 Statistical Analysis

The experimental data from the 2023 and 2024 growing seasons were pooled and subjected to analysis of variance (ANOVA) appropriate for a randomised block design (RBD). Statistical analyses were performed using Microsoft Excel. Treatment means were compared using the critical difference (CD) test at the 5% significance level ($P \leq 0.05$). The standard error of the mean (SEm ±) and critical difference (CD) were calculated and reported for the measured parameters.

3. Results and Discussion

3.1 Plant Height

Plant height was significantly influenced by integrated nutrient management treatments at 25 DAS, 50 DAS and harvest (Table 1). In the pooled analysis, plant height ranged from 14.58 to 18.91 cm at 25 DAS, 31.38 to 43.84 cm at 50 DAS and 39.35 to 54.17 cm at harvest. Treatment T_{12} (50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}) recorded the highest plant height at all three stages, with values of 18.91, 43.84 and 54.17 cm, respectively. These values represented increases of 29.70%, 39.71% and 37.66% over the control and 17.82%, 26.45% and 24.33% over 100% RDF at the respective stages. Based on the reported critical difference, T_{12} was statistically at par with T_{10}, T_{11}, T_{16}, T_{17} and T_{18} at 25 DAS. At 50 DAS, T_{12} was statistically at par with T_{18}. At harvest, T_{12} was statistically at par with T_{11}, T_{17} and T_{18}. The greater plant height observed under several integrated treatments is consistent with a crop response to the combined nutrient sources. Although the amendments can influence nutrient supply and soil conditions, plant-height measurements alone do not identify the processes underlying these responses. Similar responses to integrated nutrient management have been reported by Arunkumar and Thippeshappa (2020) and Yuganthra *et al.* (2023).

Table 1. Effect of integrated nutrient management on plant height (cm) of blackgram at different growth stages

Treatment details	25 DAS (cm)	50 DAS (cm)	Harvest (cm)
T_1: Control	14.58	31.38	39.35
T_2: 100% RDF	16.05	34.67	43.57
T_3: BC at 2 t ha^{-1}	15.52	32.54	40.98
T_4: BC at 4 t ha^{-1}	15.79	33.40	42.04
T_5: FYM at 4 t ha^{-1}	16.33	36.14	45.30
T_6: VC at 1.3 t ha^{-1}	16.49	37.05	46.30
T_7: 50% RDF + BC at 2 t ha^{-1} + FYM at 2 t ha^{-1}	17.23	38.86	48.50
T_8: 50% RDF + BC at 2 t ha^{-1} + VC at 0.6 t ha^{-1}	17.74	40.18	50.43
T_9: 50% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	18.04	40.79	51.08
T_{10}: 50% RDF + BC at 4 t ha^{-1} + FYM at 2 t ha^{-1}	18.20	41.62	52.03
T_{11}: 50% RDF + BC at 4 t ha^{-1} + VC at 0.6 t ha^{-1}	18.73	42.18	52.81
T_{12}: 50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	18.91	43.84	54.17
T_{13}: 75% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1}	17.50	39.27	49.03
T_{14}: 75% RDF + BC at 2 t ha^{-1} + VC at 0.3 t ha^{-1}	17.03	38.21	47.75
T_{15}: 75% RDF + BC at 2 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	17.88	40.46	50.80
T_{16}: 75% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1}	18.12	41.06	51.57
T_{17}: 75% RDF + BC at 4 t ha^{-1} + VC at 0.3 t ha^{-1}	18.58	42.01	52.71
T_{18}: 75% RDF + BC at 4 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	18.78	42.95	53.26
SE(m)±	0.28	*0.52*	*0.52*
CD (p=0.05)	0.80	*1.45*	*1.46*

Note: DAS = days after sowing; RDF = recommended dose of fertiliser; BC = biochar; FYM = farmyard manure; VC = vermicompost; SEm(±) = standard error of the mean; CD = critical difference

3.2 Number of Branches

The number of branches plant^{-1} was significantly influenced by the integrated nutrient management treatments at 50 DAS and harvest, while no branches were recorded at 25 DAS (Table 2). In the pooled analysis, branch number ranged from 2.86 to 4.67 plant^{-1} at 50 DAS and from 4.33 to 5.43 plant^{-1} at harvest. At 50 DAS, T_9 (50% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}) recorded the highest numerical value of 4.67 branches plant^{-1}, followed by T_{12} with 4.61 branches plant^{-1}. At harvest, T_{12} recorded the highest value of 5.43 branches plant^{-1}. Compared with the control, T_{12} increased branch number by 50.65% at 50 DAS and 25.40% at harvest, while the increases over 100% RDF were 23.92% and 18.04%, respectively. The greater branch production under integrated treatments coincided with higher plant-height values in several treatments, indicating consistent differences in vegetative growth. The continued increase in branch number up to harvest under T_{12} suggests that the treatment supported sustained branch development. Comparable improvements in branching under integrated nutrient management have been reported by Mahamud *et al.* (2022) and Behera and Mohapatra (2022).

3.3 Chlorophyll Index

The leaf chlorophyll index was not significantly influenced by integrated nutrient management treatments at 50 DAS; however, significant treatment differences were observed at harvest (Table 2). In the pooled analysis, chlorophyll readings ranged from 33.55 to 39.05 SPAD units at 50 DAS and from 33.10 to 38.30 SPAD units at harvest. T_{12} (50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}) recorded the highest readings of 39.05 and 38.30 SPAD units, respectively. Numerically, T_{12} recorded 16.39% and 15.71% higher chlorophyll readings than the control, and 11.89% and 11.34% higher readings than 100% RDF at 50 DAS and harvest, respectively. The numerical pattern of SPAD readings under T_{12} was consistent with its higher vegetative growth measurements, although the difference in SPAD values was not significant at 50 DAS. As an indirect index of leaf chlorophyll, SPAD readings do not identify any particular nutrient-retention or soil-improvement process. Similar improvements in chlorophyll content under integrated nutrient management involving vermicompost and biochar have been reported by Monisha *et al.* (2024) and Hafez *et al.* (2021).

Table 2. Effect of integrated nutrient management on primary branches plant^{-1} and leaf chlorophyll index (SPAD) of blackgram

Treatment details	Branches (plant^{-1}) 50 DAS	Branches (plant^{-1}) Harvest	SPAD 50 DAS	SPAD Harvest
T_1: Control	3.06	4.33	33.55	33.10
T_2: 100% RDF	3.72	4.60	34.90	34.40
T_3: BC at 2 t ha^{-1}	2.86	4.50	34.00	33.60
T_4: BC at 4 t ha^{-1}	3.08	4.50	34.45	33.90
T_5: FYM at 4 t ha^{-1}	3.76	4.67	35.60	35.20
T_6: VC at 1.3 t ha^{-1}	3.98	4.77	36.00	35.40
T_7: 50% RDF + BC at 2 t ha^{-1} + FYM at 2 t ha^{-1}	3.53	4.90	36.65	36.15
T_8: 50% RDF + BC at 2 t ha^{-1} + VC at 0.6 t ha^{-1}	4.29	4.93	37.45	36.80
T_9: 50% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	4.67	5.27	37.75	37.10
T_{10}: 50% RDF + BC at 4 t ha^{-1} + FYM at 2 t ha^{-1}	4.06	5.17	38.00	37.35
T_{11}: 50% RDF + BC at 4 t ha^{-1} + VC at 0.6 t ha^{-1}	4.13	5.17	38.50	37.80
T_{12}: 50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	4.61	5.43	39.05	38.30
T_{13}: 75% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1}	3.41	4.87	37.15	36.55
T_{14}: 75% RDF + BC at 2 t ha^{-1} + VC at 0.3 t ha^{-1}	4.21	4.90	36.40	35.85
T_{15}: 75% RDF + BC at 2 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	3.66	5.03	37.35	36.80
T_{16}: 75% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1}	4.49	5.17	37.85	37.25
T_{17}: 75% RDF + BC at 4 t ha^{-1} + VC at 0.3 t ha^{-1}	4.09	5.17	38.25	37.55
T_{18}: 75% RDF + BC at 4 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	4.44	5.40	38.75	38.00
SE(m)±	*0.29*	*0.13*	*0.68*	*0.54*
CD (p=0.05)	*0.81*	*0.37*	*NS*	*1.52*

Note: DAS = days after sowing; RDF = recommended dose of fertiliser; BC = biochar; FYM = farmyard manure; VC = vermicompost; SEm(±) = standard error of the mean; CD = critical difference

3.4 The Number of Pods Plant^{-1}

The number of pods plant^{-1} was significantly influenced by the integrated nutrient management treatments (Table 3). In the pooled analysis, the number of pods ranged from 30.57 to 36.46 pods plant^{-1}. T_{12} (50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}) recorded the highest number of pods (36.46 plant^{-1}), which was 19.27% higher than the control and 13.41% higher than 100% RDF. Based on the pooled CD of 1.98, T_{12} was statistically at par with T_9, T_{10}, T_{11}, T_{15}, T_{16}, T_{17} and T_{18}. The higher number of pods under T_{12} coincided with greater plant height and branching at harvest. This pattern is consistent with the contribution of reproductive yield components to seed production, without establishing a specific soil-mediated mechanism. Similar improvements in yield attributes under integrated nutrient management have been reported by Meena *et al.* (2021) and Verma *et al.* (2025).

3.5 1,000-seed Weight

1,000-seed weight ranged from 34.22 to 35.45 g in the pooled analysis (Table 3). T_{12} (50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}) recorded the highest numerical 1,000-seed weight of 35.45 g, representing numerical increases of 3.59% over the control and 2.75% over 100% RDF. However, the treatment effect on 1,000-seed weight was non-significant. These findings were consistent with those of Pandian *et al.* (2016) and Wang *et al.* (2018).

Table 3. Effect of integrated nutrient management on seeds pod^{-1}, pods plant^{-1} and 1,000-seed weight of blackgram

Treatment details	Seeds pod^{-1}	Pods plant^{-1}	1,000-seed weight (g)
T_1: Control	4.17	30.57	34.22
T_2: 100% RDF	4.37	32.15	34.50
T_3: BC at 2 t ha^{-1}	4.20	31.22	34.35
T_4: BC at 4 t ha^{-1}	4.30	31.63	34.40
T_5: FYM at 4 t ha^{-1}	4.43	32.65	34.69
T_6: VC at 1.3 t ha^{-1}	4.50	33.17	34.59
T_7: 50% RDF + BC at 2 t ha^{-1} + FYM at 2 t ha^{-1}	4.70	33.66	34.82
T_8: 50% RDF + BC at 2 t ha^{-1} + VC at 0.6 t ha^{-1}	4.80	34.21	34.94
T_9: 50% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	4.90	34.58	35.00
T_{10}: 50% RDF + BC at 4 t ha^{-1} + FYM at 2 t ha^{-1}	5.00	34.78	35.09
T_{11}: 50% RDF + BC at 4 t ha^{-1} + VC at 0.6 t ha^{-1}	5.13	35.51	35.26
T_{12}: 50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	5.37	36.46	35.45
T_{13}: 75% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1}	4.57	33.19	34.77
T_{14}: 75% RDF + BC at 2 t ha^{-1} + VC at 0.3 t ha^{-1}	4.80	33.79	34.88
T_{15}: 75% RDF + BC at 2 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	4.87	34.62	34.99
T_{16}: 75% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1}	4.97	34.73	35.05
T_{17}: 75% RDF + BC at 4 t ha^{-1} + VC at 0.3 t ha^{-1}	5.10	35.40	35.21
T_{18}: 75% RDF + BC at 4 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	5.27	35.75	35.34
SE(m)±	*0.11*	*0.7*	*0.28*
CD (p=0.05)	*0.32*	*1.98*	*NS*

Note: DAS = days after sowing; RDF = recommended dose of fertiliser; BC = biochar; FYM = farmyard manure; VC = vermicompost; SEm(±) = standard error of the mean; CD = critical difference

3.6 Seed and Stover Yield

Integrated nutrient management treatments significantly influenced seed and stover yields of blackgram (Table 4). In the pooled analysis, seed yield ranged from 408.06 to 634.87 kg ha^{-1}. T_{12} (50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}) recorded the highest seed yield of 634.87 kg ha^{-1}, representing increases of 55.58% over the control and 25.72% over 100% RDF. Based on the pooled CD of 52.01 kg ha^{-1}, T_{12} was statistically at par with T_8, T_9, T_{10}, T_{11}, T_{14}, T_{15}, T_{16}, T_{17} and T_{18}. The highest pooled stover yield was also recorded under T_{12} (1324.51 kg ha^{-1}), representing increases of 49.65% over the control and 24.53% over 100% RDF, and was statistically at par with T_8, T_9, T_{10}, T_{11}, T_{14}, T_{15}, T_{16}, T_{17} and T_{18}. The larger seed and stover yields under T_{12} coincided with higher plant height, branch number at harvest, pods per plant and seeds per pod. These observed associations support an interpretation based on improved yield components rather than a measured change in nutrient retention or soil properties. Similar improvements in growth and yield of blackgram under integrated nutrient management have been reported by Yuganthra *et al.* (2023), Verma *et al.* (2025) and Kumar *et al.* (2025).

Relative to the control, T_{12} produced an additional 226.81 kg ha^{-1} of seed and 439.41 kg ha^{-1} of stover; relative to 100% RDF, the increases were 129.88 and 260.87 kg ha^{-1}, respectively (Table 4). The same treatment produced 36.46 pods plant^{-1} and 5.37 seeds pod^{-1}, compared with 30.57 pods plant^{-1} and 4.17 seeds pod^{-1} under the control (Table 3). Both differences exceeded their respective critical differences of 1.98 pods plant^{-1} and 0.32 seeds pod^{-1}, whereas the effect on 1,000-seed weight was non-significant. Thus, the higher seed yield coincided with changes in pod and seed numbers rather than a statistically detectable difference in individual seed weight. Although T_{12} recorded the highest numerical yields, T_8, T_9, T_{10}, T_{11}, T_{14}, T_{15}, T_{16}, T_{17} and T_{18} were statistically comparable for seed yield, consistent with the reported CD of 52.01 kg ha^{-1}. These comparisons indicate that several integrated nutrient-management combinations were associated with similar yield performance under the conditions evaluated.

3.7 Seed Protein

Seed protein content ranged from 22.01 to 23.26% in the pooled analysis (Table 4). T_{12} recorded a seed protein content of 23.26%, representing increases of 5.68% over the control and 4.07% over 100% RDF. This value was statistically at par with T_9, T_{10}, T_{11}, T_{16}, T_{17} and T_{18}. Seed protein content was estimated from seed nitrogen using a conversion factor of 6.25; therefore, the higher calculated protein content reflects differences in seed nitrogen concentration rather than a direct measurement of soil nitrogen availability or whole-plant nitrogen uptake. Similar improvements in blackgram protein content under integrated nutrient management were reported by Kadam *et al.* (2020), Amruta *et al.* (2016) and Tyagi and Singh (2019).

Table 4. Effect of integrated nutrient management on seed and stover yield, and protein content of blackgram

Treatment details	Seed yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Seed protein (%)
T_1: Control	408.06	885.10	22.01
T_2: 100% RDF	504.99	1063.64	22.35
T_3: BC at 2 t ha^{-1}	445.64	912.10	22.14
T_4: BC at 4 t ha^{-1}	475.51	1097.42	22.27
T_5: FYM at 4 t ha^{-1}	528.75	1169.31	22.41
T_6: VC at 1.3 t ha^{-1}	552.65	1151.15	22.47
T_7: 50% RDF + BC at 2 t ha^{-1} + FYM at 2 t ha^{-1}	580.63	1216.43	22.59
T_8: 50% RDF + BC at 2 t ha^{-1} + VC at 0.6 t ha^{-1}	595.90	1240.14	22.70
T_9: 50% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	602.93	1254.34	22.84
T_{10}: 50% RDF + BC at 4 t ha^{-1} + FYM at 2 t ha^{-1}	613.03	1278.53	22.96
T_{11}: 50% RDF + BC at 4 t ha^{-1} + VC at 0.6 t ha^{-1}	623.03	1297.06	23.13
T_{12}: 50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}	634.87	1324.51	23.26
T_{13}: 75% RDF + BC at 2 t ha^{-1} + FYM at 1 t ha^{-1}	573.73	1193.19	22.50
T_{14}: 75% RDF + BC at 2 t ha^{-1} + VC at 0.3 t ha^{-1}	588.83	1225.73	22.65
T_{15}: 75% RDF + BC at 2 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	600.56	1252.64	22.76
T_{16}: 75% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1}	608.30	1267.32	22.88
T_{17}: 75% RDF + BC at 4 t ha^{-1} + VC at 0.3 t ha^{-1}	620.16	1292.97	23.04
T_{18}: 75% RDF + BC at 4 t ha^{-1} + FYM at 0.5 t ha^{-1} + VC at 0.15 t ha^{-1}	630.45	1312.18	23.20
SE(m)±	*18.43*	*37.89*	*0.15*
CD (p=0.05)	*52.01*	*106.92*	*0.42*

Note: DAS = days after sowing; RDF = recommended dose of fertiliser; BC = biochar; FYM = farmyard manure; VC = vermicompost; SEm(±) = standard error of the mean; CD = critical difference

4. Conclusion

The two-year field experiment demonstrated that integrated nutrient management influenced the growth, yield attributes, productivity and seed protein content of blackgram. Among the 18 treatments, T_{12} (50% RDF + BC at 4 t ha^{-1} + FYM at 1 t ha^{-1} + VC at 0.3 t ha^{-1}) recorded the highest numerical values for plant height, branch number at harvest, chlorophyll readings, pods plant^{-1}, seeds pod^{-1}, 1,000-seed weight, seed yield, stover yield and seed protein content in the pooled analysis. It produced a seed yield of 634.87 kg ha^{-1} and a seed protein content of 23.26%, representing increases of 55.58% and 5.68%, respectively, over the control. Several responses under T_{12} were statistically comparable with those under other integrated nutrient management treatments. These findings suggest that combining 50% RDF with biochar, FYM and vermicompost is a promising approach to improving blackgram productivity and seed protein content under the conditions of the present study. Further studies across locations, seasons and soil types are needed to confirm the wider applicability of this treatment.

5. Limitations

The study evaluated one blackgram cultivar at a single location over two kharif seasons. Its crop-response results therefore apply most directly to the soil and growing conditions tested. Although biochar and organic amendments have potential effects on soil chemical and physical properties, the presented measurements do not establish those mechanisms. Multi-location evaluation with year-specific statistical assessment and relevant soil measurements would assist in determining the consistency and explanation of the observed responses.

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Declaration of AI Use

This manuscript was prepared through the intellectual contributions of the author(s) to the study design, data analysis, interpretation of results, and scholarly content. Grammarly and ChatGPT were used solely to assist with grammatical refinement and reference formatting during manuscript revision. The author(s) accept full responsibility for the accuracy, integrity, and final content of the manuscript.

Competing Interests

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Amruta, N., Devaraju, P. J., Mangalagowri, M., Kiran, S. P., Ranjitha, H. P., & Teli, K. (2016). Effect of integrated nutrient management and spacing on seed quality parameters of black gram cv. LBG-625 (Rashmi). *Journal of Applied and Natural Science, 8(1),* 340–345. https://doi.org/10.31018/jans.v8i1.797.

Arunkumar, B. R., & Thippeshappa, G. N. (2020). Residual effect of levels of biochar and FYM on growth, yield and nutrient uptake by green gram (*Vigna radiata* L.) crop in sandy loam soil. *International Journal of Current Microbiology and Applied Sciences, 9(2),* 695–707. https://doi.org/10.20546/ijcmas.2020.902.085.

Bajpayi, Y., Vishwakarma, M., Panchal, V., & Kawde, A. (2026). Effects of biochar, vermicompost and FYM on soybean productivity and nutrient use efficiency in Vertisols. *Journal of Scientific Research and Reports, 32(7),* 1–14. https://doi.org/10.9734/jsrr/2026/v32i74283.

Behera, P., & Mohapatra, A. (2022). Effect of integrated nutrient management practices on productivity of blackgram (*Vigna mungo). Indian Journal of Agricultural Sciences, 92(10),* 1283–1285. https://doi.org/10.56093/ijas.v92i10.125429.

Bonepally, R., Umesha, C., & Meshram, M. R. (2021). Influence of spacing and phosphorus levels on growth and yield of blackgram (*Vigna mungo* L.). *Biological Forum – An International Journal, 13(1),* 82–85. https://www.researchtrend.net/bfij/pdf/14%20Influence%20of%20Spacing%20and%20Phosphorus%20Levels%20on%20Growth%20and%20Yield%20of%20Blackgram%20_Vigna%20mungo%20L._%20Bonepally%20Rashmitha%20663.pdf.

Das, S., Teron, R., Duary, B., Bhattacharya, S. S., & Kim, K.-H. (2019). Assessing C–N balance and soil rejuvenation capacity of vermicompost application in a degraded landscape: A study in an alluvial river basin with *Cajanus cajan. Environmental Research, 177,* Article 108591. https://doi.org/10.1016/j.envres.2019.108591.

Dissanayake, L., Omidvar, N., Farrar, M. B., Joseph, S., Guo, L., Reverchon, F., Gallart, M., Kichamu-Wachira, E., Muqaddas, B., & Hosseini Bai, S. (2026). Applying biochar with fertilisers decreases nitrogen and phosphorus leaching and improves phosphorus availability: A meta-analysis. *GCB Bioenergy, 18(9),* e70165. https://doi.org/10.1111/gcbb.70165.

Hafez, E. M., Omara, A. E. D., Alhumaydhi, F. A., & El-Esawi, M. A. (2021). Minimizing hazard impacts of soil salinity and water stress on wheat plants by soil application of vermicompost and biochar. *Physiologia Plantarum, 172(2),* 587–602. https://doi.org/10.1111/ppl.13261.

Han, M., Zhang, J., Zhang, L., & Wang, Z. (2023). Effect of biochar addition on crop yield, water and nitrogen use efficiency: A meta-analysis. *Journal of Cleaner Production, 420,* Article 138425. https://doi.org/10.1016/j.jclepro.2023.138425.

Hasan, A. K., Islam, S. S., Jahan, M., Kheya, S. A., Uddin, M. R., Islam, M. S., & Khomphet, T. (2024). Synergistic effects of vermicompost and biochar amendments on soil fertility and wheat productivity in Bangladesh floodplain soils. *Scientifica, 2024,* Article 6624984. https://doi.org/10.1155/sci5/6624984.

Kadam, Y. D., Laharia, G. S., Age, A. B., Jadhao, S. D., Mali, D. V., Rakhonde, O. S., Sonune, B. A., Kankal, D. S., & Dange, N. R. (2020). Effect of biochar, FYM and nitrogen on uptake of nutrients, quality and yield of blackgram. *International Research Journal of Pure & Applied Chemistry, 21(22),* 9–16. https://doi.org/10.9734/IRJPAC/2020/v21i2230292.

Kumar, A., Kumar, V., Pandey, V., Tripathi, S. S., & Sharma, R. K. (2025). Evaluation of effectiveness of integrated nutrient management on plant growth, quality and quantity of summer black gram (*Vigna mungo L. Hepper). Plant Archives, 25(2),* 2714–2717. https://doi.org/10.51470/PLANTARCHIVES.2025.v25.no.2.392.

Liu, X., Zhang, J., Wang, Q., Chang, T., Shaghaleh, H., & Hamoud, Y. A. (2022). Improvement of photosynthesis by biochar and vermicompost to enhance tomato (*Solanum lycopersicum* L.) yield under greenhouse conditions. *Plants, 11(23),* Article 3214. https://doi.org/10.3390/plants11233214.

Mahamud, M. A., Rahman, M. M., Hassan, M. A., Bahadur, M. M., Sabil, A. S., Imran, S., & Paul, N. C. (2022). Assessing the influence of integrated nutrient management on growth and yield of black gram (*Vigna mungo* L.). *Archives of Agriculture and Environmental Science, 7(3),* 407–414. https://doi.org/10.26832/24566632.2022.0703015.

Meena, H., Bharati, V., Dwivedi, D. K., Singh, S. K., Choudhary, R., & Singh, H. (2021). Effect of integrated nutrient management on yield attributes and yield of black *gram cv. PU-31. Legume Research, 44(11),* 1353–1357. https://doi.org/10.18805/LR-4635.

Monisha, S., Krishnaprabu, S., Immanuel, R. R., & Ravichandran, S. (2024). Studies on the effect of integrated nutrient management on growth parameters of irrigated blackgram. *International Journal of Research in Agronomy, 7(6S),* 413–415. https://doi.org/10.33545/2618060X.2024.v7.i6Sf.886.

Okine, J. N. A., Bamfo, B. S., Nkrumah, C., Azeko, M., Mashud, R., & Brobbey, H. A. (2026). Biochar for ameliorating soil pH, soil health, crop yield and greenhouse gas emission: A review. *Journal of Global Agriculture and Ecology, 18(2),* 63–76. https://doi.org/10.56557/jogae/2026/v18i210492.

Pandian, K., Subramaniayan, P., Gnasekaran, P., & Chitraputhirapillai, S. (2016). Effect of biochar amendment on soil physical, chemical and biological properties and groundnut yield in rainfed Alfisol of semi-arid tropics. *Archives of Agronomy and Soil Science, 62(9),* 1293–1310. https://doi.org/10.1080/03650340.2016.1139086.

Rambuatsaiha, G., Gohain, T., & Kikon, N. (2017). Optimization of organic nutrient sources for green gram (*Vigna radiata* L. Wilczek) under rainfed conditions. *Indian Journal of Agricultural Research, 51(5),* 443–447. https://doi.org/10.18805/IJARe.A-4842.

Thakur, A., Kumar, A., Kumar, C. V., Kiran, B. S., Kumar, S., & Athokpam, V. (2021). A review on vermicomposting: By-products and its importance. *Plant Cell Biotechnology and Molecular Biology, 22(11–12),* 156–164. https://ikprress.org/index.php/PCBMB/article/view/5993.

Tyagi, P. K., & Singh, V. K. (2019). Effect of integrated nutrient management on growth, yield and nutrients uptake of summer blackgram (*Vigna mungo). Annals of Plant and Soil Research, 21(1),* 30–35. https://www.gkvsociety.com/control/uploads/2062036.pdf.

Verma, A. K., Singh, A. K., Singh, A., Verma, R., Kumar, A., Singh, A., & Singh, U. (2025). Productivity of blackgram *(Vigna mungo L.)* influenced by biofertilizers and variable sources of nutrients. *Legume Research, 48(10),* 1766–1770. https://doi.org/10.18805/LR-5514.

Wang, L., Xue, C., Nie, X., Liu, Y., & Chen, F. (2018). Effects of biochar application on soil potassium dynamics and crop uptake. *Journal of Plant Nutrition and Soil Science, 181(5),* 635–643. https://doi.org/10.1002/jpln.201700528.

Yuganthra, B., Rajendran, K., Joseph, P. A., Katharine, S. P., Sharmili, K., & Balaganesh, B. (2023). Effect of integrated nutrient management on growth and yield of irrigated blackgram *(Vigna mungo L.). International Journal of Environment and Climate Change, 13(8),* 1566–1571. https://doi.org/10.9734/ijecc/2023/v13i82105.

Zhang, S., Zhu, Q., de Vries, W., Ros, G. H., Chen, X., Muneer, M. A., Zhang, F., & Wu, L. (2023). Effects of soil amendments on soil acidity and crop yields in acidic soils: A world-wide meta-analysis. *Journal of Environmental Management, 345,* Article 118531. https://doi.org/10.1016/j.jenvman.2023.118531.

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