PLANT SCIENCE TODAY
Vol 12(sp4): 1-7
https://doi.org/10.14719/pst.7754

eISSN 2348-1900

RESEARCH ARTICLE

Response of black gram (*Vigna mungo* L.) to organic nutrient sources and their effect on soil properties and yield attributes in Western Himalayan region of India

Sachin[1], Janardan Singh[1], Rahul Sharma[1]*, Akashdeep Singh[2]*, Kunal Narwal[3], Bharat Bhushan Rana[1], Abhay Verma[1] & Suraj Sharma[1]

[1]Department of Agronomy, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur 176 062, Himachal Pradesh, India
[2]Department of Agronomy, Dr Khem Singh Gill Akal College of Agriculture, Eternal University, Baru Sahib 173 101, Himachal Pradesh, India
[3]Department of Agriculture, Sanskaram University Jhajjar124 108, Haryana, India

*Correspondence email - sharmarahul.alampur@gmail.com; akash.agercultura@gmail.com

Received: 15 February 2025; Accepted: 07 August 2025; Available online: Version 1.0: 28 October 2025

Cite this article: Sachin, Janardan S, Rahul S, Akashdeep S, Kunal N, Bharat BR, Abhay V, Suraj S. Response of black gram (*Vigna mungo* L.) to organic nutrient sources and their effect on soil properties and yield attributes in Western Himalayan region of India. Plant Science Today. 2025; 12(sp4): 1-7. https://doi.org/10.14719/pst.7754

Abstract

As the second most significant food after cereals, pulses are high in protein and serve a vital role in Indian agriculture. By improving the nitrogen levels, they encourage long term fertility and maintain system sustainability. The present study evaluated the impact of varied organic nutrient sources on black gram growth, yield attributes, soil health and economic returns. The application of biofertilizers (*Rhizobium* + PSB) in combination with vermicompost and vermiwash resulted in a 12.3 % reduction in days to flowering compared to absolute control, while physiological maturity remained unaffected. Plant height increased by 20.4 % under the same treatment. Yield attributes such as pods per plant (21.2), seeds per pod (7.1) and primary branches per plant (6.5) improved significantly, with increases of 24.7 %, 26.2 % and 24.6 %, respectively. Seed yield increased by 43.5 % in comparison to treatment without application of any organic fertilizer. Significantly highest seed yield of 1193 kg ha^{-1} was recorded due to the combined application of biofertilizers (*Rhizobium* and PSB), vermicompost @ 7.5 t ha^{-1} and vermiwash (1:10). Post-harvest soil nutrient availability showed significant improvement, with increases in available nitrogen, phosphorus and potassium owing to substantial increase in microbial population by 36.9 % bacterial count, 39.3 % fungal count and 34.7 % actinomycete count compared to absolute control. This corresponds to an increase in enzymatic activity (4.8 µg TPF g^{-1} soil h^{-1}) as well as soil microbial biomass carbon (132.8 4.8 µg g^{-1} soil). The findings highlight the potential of integrated organic nutrient management for enhancing crop productivity, soil fertility and economic sustainability but also for fostering resilient agricultural systems. The combined application of different organic nutrient sources offers a viable and environmentally sound solution to maintaining log-term ecological balance while also contributing to food security.

Keywords: biofertilizers; farmyard manure; organic farming; pulse; soil biology; vermicompost; yield

Introduction

Black gram (*Vigna mungo* L.), also referred to as 'urad bean' or 'black lentil,' is a vital pulse crop belonging to the family Leguminosae. It serves as an important source of dietary protein, particularly for vegetarian populations in many countries. Despite the increasing per capita net availability of food grains, which rose from 144.1 kg $year^{-1}$ in 1951 to 179.6 kg $year^{-1}$ in 2019, the availability of pulses has declined significantly, from 25 kg $year^{-1}$ in 1961 to 17.5 kg $year^{-1}$ in 2019 (1). This decline poses a serious risk to the nutritional security and agricultural sustainability. Besides its role in human nutrition, black gram is nutritionally rich, providing 25.2 g of protein, 18.3 g of dietary fibre and essential minerals such as calcium (138 mg), magnesium (267 mg), phosphorus (379 mg), potassium (983 mg) and zinc (3.35 mg) (2). It is cultivated over an estimated 46.33 lakh hectares, with a production of 27.76 lakh tonnes and an average productivity of 599 kg ha^{-1} (3). The crop thrives in hot and humid climates and is well-suited for multiple cropping systems and intercropping due to its short duration.

The global agricultural landscape is facing unprecedented challenges with the world projected to reach a global population of 9 billion people by mid-century. Conventional agricultural systems that are historically dependent on excessive available synthetic chemical fertilizer and pesticides have resulted in the stagnation of agricultural production and a significant decline in environmental quality (4, 5). Consequently, soil productivity is on a persistent downward decline as evidenced by the widespread shortage of micronutrients and the loss of important soil physical and biological parameters. This has created an urgent necessity for a shift to sustainable and ecological farming systems that can remediate soil productivity without compromising or increasing agricultural output.

In response to these increasing challenges, organic and natural farming systems emerged as potentially effective strategies and practices to alleviate soil degradation and support agricultural resilience over time. Organic and natural farming systems endorse the rational use of farm based resources, such as fertilizers prepared from cow dung and cow urine. They also promote the holistic health of the soil, the success of nutrient cycling and have been shown to vastly increase the water holding capacity of soils (6). Although the advantages of such approaches are becoming increasingly accepted, detailed studies investigating their individual influence on black gram pulse crops, especially regarding their effects on the soil properties, yield characteristics and economics of their production under varying agricultural conditions in India, are still limited. A positive impact of the combined application of farmyard manure and *Ghanajiwamrita* on the growth of cowpea whereas the application of vermicompost to mung bean resulted in 44.9 % increase in the yield (7, 8).

Given these challenges and the growing need for sustainable agricultural practices, the present study was undertaken to evaluate the effects of organic and natural farming based nutrient sources on soil properties, yield attributes and the yield of black gram. By assessing the impact of organic fertilizers and biofertilizers on crop performance, soil fertility and economic viability, this research aims to establish a sustainable and cost-effective nutrient management approach that benefits both productivity and environmental health.

Materials and Methods

Experimental site

The field experiment was conducted during the *kharif* season of 2021 at Model Organic Farm, Department of Organic Agriculture and Natural Farming, C S K Himachal Pradesh Krishi Vishvavidyalaya, Palampur, India. The experimental site is located at 32°06'17" N latitude and 76°32'33" E longitude and at an elevation of 1290.8 meters above mean sea level. The soil sample collected from 0-15 cm depth was processed and subjected to chemical analysis to estimate available nitrogen, phosphorus and potassium using alkaline $KMnO_4$ method (9), Olsen's method (10) and neutral ammonium acetate method (11), respectively. The soil at the experimental site was acidic in reaction (pH 5.7) (12), silty clay loam in texture (13), low in available nitrogen (227.4 kg/ha), medium in available phosphorus (18.5 kg/ha) and medium in available potassium (196.7 kg/ha).

Treatment details

The experiment was laid out in Randomized Complete Block Design (RCBD) with eight treatments and replicated thrice (see below). Black gram variety UG 218 was sown at an inter row spacing of 30 cm and plant to plant spacing of 10 cm. The seed rate used was 20 kg ha^{-1}, whereas the plot size was 9 m^2 (3 m x 3 m). The application rate of *Bijamrita*, used for seed treatment, was 100 mL kg^{-1} while the soil application of *Jiwamrita* was done at the rate of 500 L ha^{-1}.

Statistical analysis

The data were statistically analysed using a Randomized Block Design and the Analysis of Variance (ANOVA) (14). Treatment means were compared at a 5 % level of significance, with post-hoc comparisons performed using Fisher's Least Significant Difference (LSD) test. Data visualization was achieved using the R packages "agricolae," "ggplot2," "ggpubr" and "ggsci" within RStudio Version 2024.04.0+735.

Results and Discussion

Effect on growth attributes

The nutrient application using varied organic input sources significantly influenced days to flowering and plant height, whereas days to physiological maturity remained unaffected (Fig. 1). Significantly taller blackgram plants were recorded under T7 (biofertilizers in combination with vermicompost and vermiwash) during the period of crop growth, though this treatment was at par with T6 (biofertilizers in conjunction with farmyard manure and vermiwash), T5 (farmyard manure along with *Rhizobium*) and T4 (sole application of farmyard manure) (Table 1). The treatment where no nutrients were applied, T8 (absolute control), had the longest duration to achieve flowering. In contrast, T7 resulted in a significant reduction in the duration to achieve flowering. This finding aligns with the understanding that robust nutrient availability supports accelerated plant development. Flowering is an important process wherein crop plants move from the vegetative phase to the reproductive phase (15). The application of phosphorus has been reported to result in flowering a day ahead in rice, while potassium application resulted in flowering 1-3 days ahead of schedule (16). The application of nutrients from organic sources not only provides macronutrients but also micronutrients that help sustain plant growth and development. Previous results reported a significant influence of organic nutrient sources on the days to flowering in okra crop (17). Although the days to physiological maturity remained unaffected by treatments, T8 attained maturity 2-4 days later than other treatments, further underscoring the importance of adequate nutrition for optimal crop development.

Effect on yield attributes and yield

The yield attributes, with the exception of test weight, were significantly influenced by various organic inputs (Fig. 2). Significantly higher number of pods per plant (21.20), number of seeds per pod (7.12) and number of primary branches per plant (6.5) were recorded under T7 (Biofertilizers (*Rhizobium* + PSB) applied in association with vermicompost and vermiwash) as compared to other treatments. Though this treatment was found to be statistically at par with T6 (biofertilizers applied in association with farmyard manure and vermiwash), T5 (combination of farmyard manure and Ghanjiwaamrita), T4 (sole application of farmyard manure) and a combination of natural

Treatment	Details
T_1	*Bijamrita* + *Jiwamrita* (5 %, 10 %, 10 % and 10 %, respectively at time of sowing, 21, 42 & 63 DAS) + mulching (10 t/ha)
T_2	*Bijamrita* + *Ghanajiwamrita* (250 kg/ha) + mulching (10 t/ha)
T_3	*Bijamrita* + *Jiwamrita* (5 %, 10 %, 10 % and 10 %, respectively at time of sowing, 21, 42 & 63 DAS) + *Ghanajiwamrita* (250 kg/ha) + mulching (10 t/ha)
T_4	Farm yard manure (10 t/ha)
T_5	Farm yard manure (10 t/ha) + *Ghanajiwamrita* (250 kg/ha)
T_6	Biofertilizers (*Rhizobium* + PSB) + farm yard manure (10 t/ha) + vermiwash at 15, 30 & 45 DAS (1:10)
T_7	Biofertilizers (*Rhizobium* + PSB) + vermicompost (7.5 t/ha) + vermiwash at 15, 30 & 45 DAS (1:10)
T_8	Absolute control

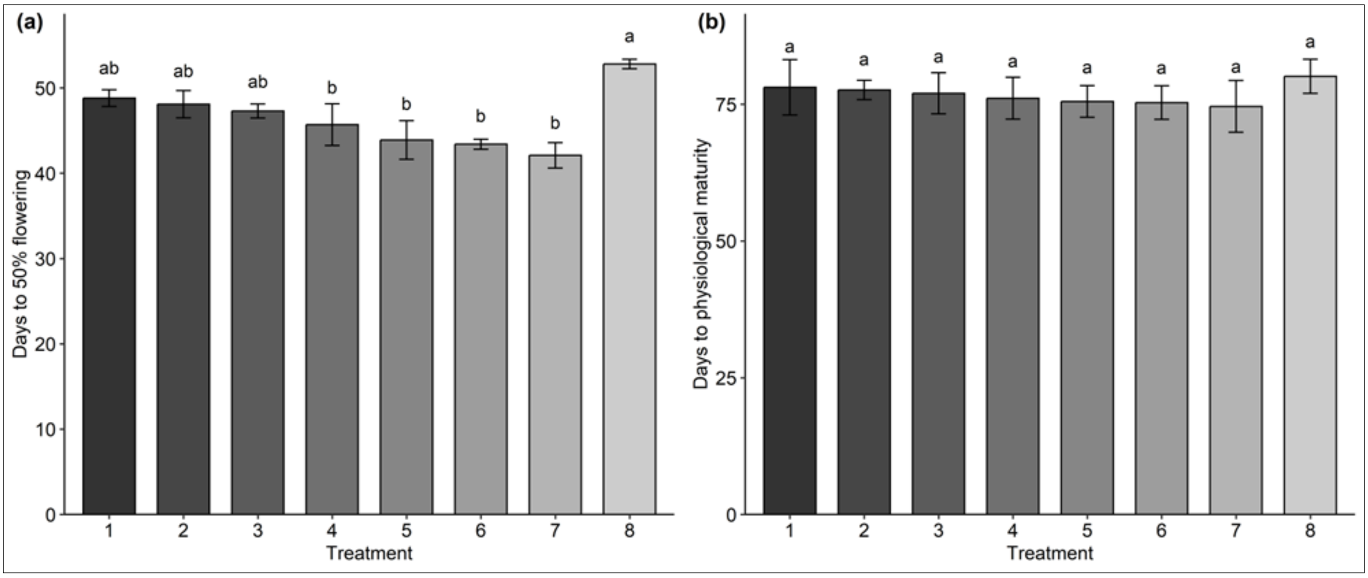

Fig. 1. Effect of different treatments on days to flowering and physiological maturity in black gram.

Table 1. Effect of different treatments on the plant height of black gram

Treatments	30 DAS	60 DAS	At harvest
T1	10.5 ± 0.2	23.7 ± 1.3	43.8 ± 2.6
T2	10.8 ± 0.4	24.2 ± 0.6	44.7 ± 0.6
T3	11.0 ± 0.2	25.5 ± 1.6	46.0 ± 2.9
T4	11.4 ± 0.6	26.9 ± 1.5	47.6 ± 1.3
T5	11.5 ± 0.2	27.3 ± 0.9	48.3 ± 1.2
T6	11.8 ± 0.1	28.5 ± 1.7	49.8 ± 0.6
T7	12.1 ± 0.7	30.1 ± 1.4	52.2 ± 3.2
T8	9.8 ± 0.9	21.8 ± 0.2	41.5 ± 1.2
LSD	1.7	5.4	7.4

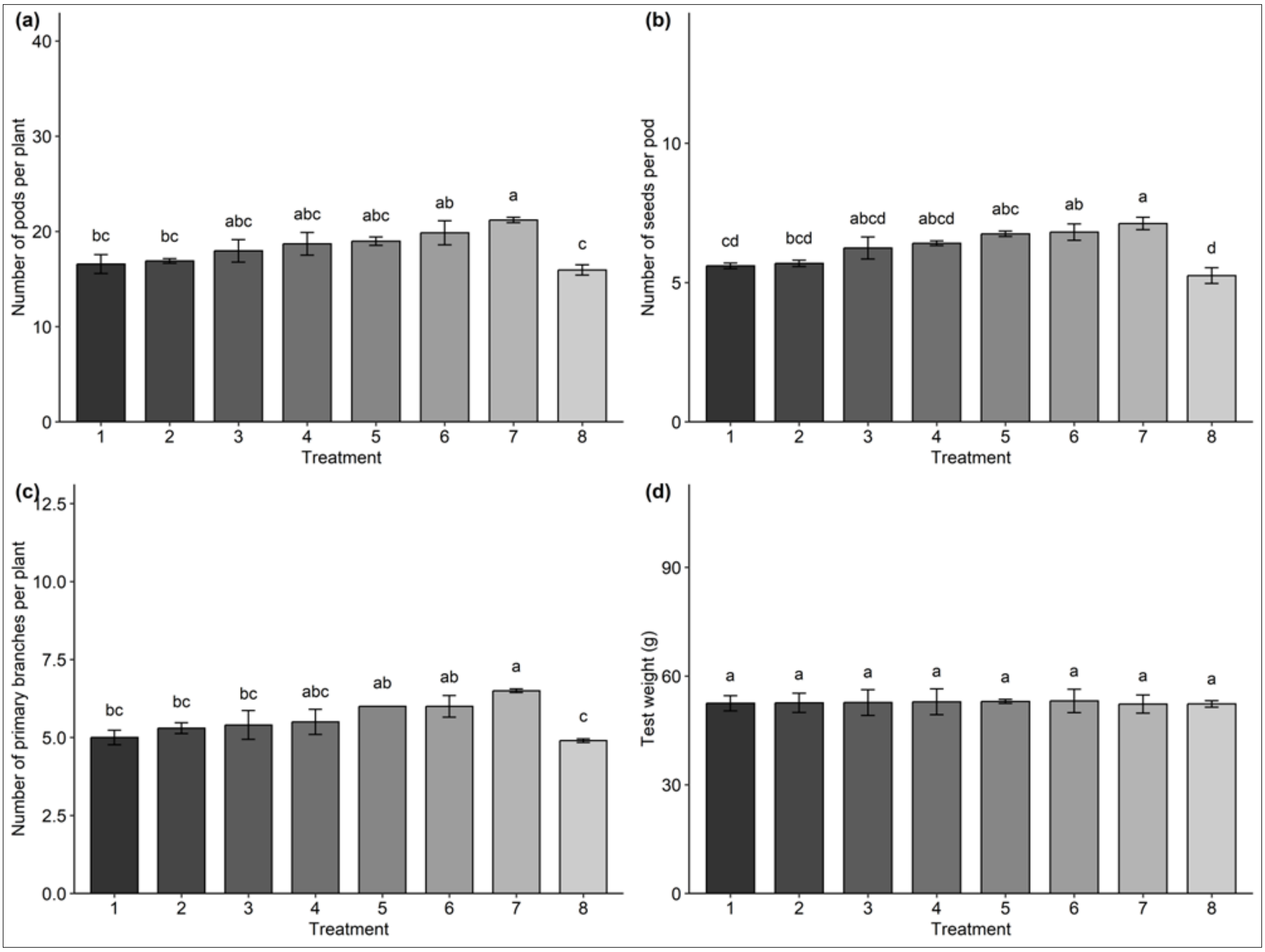

Fig. 2. Effect of different treatments on the yield attributes of blackgram.

farming formulations (T3: Bijamrita + Jiwamrita + *Rhizobium* + mulching). The yield of black gram was significantly influenced by organic formulation, resulting in significantly higher seed and straw yield under T7 (1192.9 kg ha^{-1} and 2455.09 kg ha^{-1}, respectively), though this treatment was at parity with T6 (Fig. 3). Significantly lower yields were recorded under T8 (absolute control), where no formulations were applied. The organic fertilizers tend to improve the soil chemical and biological properties, thereby providing a continuous supply of nutrients, resulting in improved yield attributes (18). The treatments with inoculation of biofertilizers further enhance the microbial population leading to improvement in nitrogen fixation. The additional nitrogen and solubilized phosphorus from the bacterial population improve the yield attributes, hence the yield of black gram (19, 20). This is consistent with findings by previous works, who reported an 11.25 % and 9.28 % increase in grain yield of corn when organic fertilizer was applied partially replacing chemical fertilizers as compared to local conventional fertilizer practices (21).

Effect on soil chemical properties and nutrient uptake

The post-harvest soil analysis demonstrated significant variations in organic carbon and available nutrients, whereas pH remained relatively stable (Table 2). The pH ranged from 5.62 to 5.66, suggesting a limited impact on soil acidity due to the short-term application of organic fertilizers and biofertilizers. The treatment with combined application of biofertilizers, vermicompost and vermiwash (T7) resulted in the highest organic carbon (0.77 %) and available nutrients (235.20 N, 24.50 P and 240.20 K kg ha^{-1}). Though this treatment was found to be at par with the conjoint application of biofertilizers, FYM and vermiwash (T6). The nutrient uptake (58.9 N, 7.1 P and 15.6 K kg ha^{-1}) was highest when nutrients were applied to the crop through T7 (Table 3). The higher values of available nutrients might be attributed to the application of biofertilizers, which enhanced nutrient mineralization and solubilization from vermicompost and FYM (22, 23). This resulted in increased availability of nutrients to the crop plants, leading to their higher uptake. Furthermore, nutrient uptake is inherently influenced by the crop yield; higher yield also contributed to higher uptake of the available nutrients under the aforementioned treatments (24). Due to the enhanced population of beneficial microorganisms, T7 significantly contributed to carbon sequestration (25). T8 (absolute control) recorded the lowest values across all the parameters, unequivocally implying the critical need for organic fertilizers for sustaining soil fertility.

Effect on soil biological properties

The microbial population in the soil, including bacteria, fungi and actinomycetes, was significantly influenced by different organic and biofertilizer-based treatments (Table 4). Among the

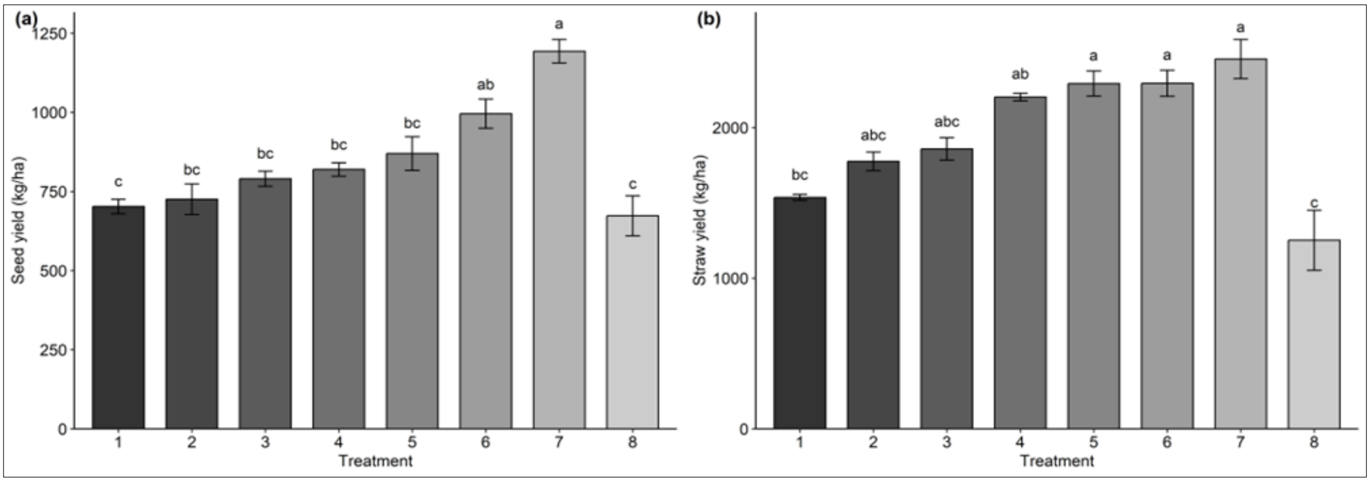

Fig. 3. Effect of different treatments in the seed and straw yield of black gram.

Table 2. Effect of different treatments on the soil chemical properties

Treatments	pH	Organic carbon (%)	Available nutrients (kg ha^{-1})		
			Nitrogen	Phosphorus	Potassium
T1	5.63 ± 0.39	0.70 ± 0.01	207.83 ± 1.77	17.10 ± 1.08	189.40 ± 3.61
T2	5.62 ± 0.38	0.70 ± 0.03	209.30 ± 7.26	19.30 ± 1.05	192.08 ± 4.27
T3	5.64 ± 0.11	0.71 ± 0.02	219.01 ± 6.11	20.70 ± 0.90	200.82 ± 13.30
T4	5.64 ± 0.25	0.73 ± 0.01	228.70 ± 3.15	22.40 ± 0.38	214.02 ± 8.50
T5	5.66 ± 0.06	0.74 ± 0.03	231.50 ± 2.63	22.90 ± 0.92	220.02 ± 1.16
T6	5.63 ± 0.25	0.75 ± 0.02	234.10 ± 3.47	23.70 ± 1.34	234.55 ± 6.43
T7	5.63 ± 0.16	0.77 ± 0.03	235.20 ± 6.65	24.50 ± 1.72	240.20 ± 9.09
T8	5.62 ± 0.10	0.68 ± 0.01	207.40 ± 1.72	13.24 ± 0.27	186.50 ± 5.43
LSD	-	0.08	21.62	6.81	35.62

Table 3. Effect of different treatments on the uptake of primary macronutrients by black gram

Treatments	Nitrogen uptake (kg ha^{-1})	Phosphorus uptake (kg ha^{-1})	Potassium uptake (kg ha^{-1})
T1	43.2 ± 1.3	4.8 ± 0.2	11.9 ± 0.3
T2	45.2 ± 1.5	5.0 ± 0.1	12.6 ± 0.2
T3	47.1 ± 2.1	5.2 ± 0.1	13.3 ± 0.1
T4	49.6 ± 0.4	5.8 ± 0.3	13.8 ± 0.2
T5	53.2 ± 1.9	6.2 ± 0.2	14.4 ± 0.8
T6	56.5 ± 1.7	6.7 ± 0.1	15.0 ± 0.3
T7	58.9 ± 0.4	7.1 ± 0.2	15.6 ± 0.6
T8	38.7 ± 2.0	4.22 ± 0.1	11.3 ± 0.3
LSD	11.5	1.6	2.6

treatments, combined application of biofertilizers, vermicompost and vermiwash (T7) exhibited the highest microbial counts across all three groups, with bacterial, fungal and actinomycete populations reaching 29.8 × 10^5, 8.9 × 10^2 and 27.3 × 10^3 CFU g^{-1} soil, respectively. This increase can be attributed to the application of vermicompost and vermiwash, which provide readily available organic matter and microbial inoculants that enhance microbial proliferation and enzymatic activity (26). The addition of biofertilizers (*Rhizobium* + PSB) further promoted microbial growth by enhancing nutrient cycling, particularly nitrogen fixation and phosphorus solubilization (27). This was followed by T6 (combined application of biofertilizers, FYM and vermiwash), which also supported a relatively high microbial population, with bacteria (27.0 × 10^5 CFU g^{-1}), fungi (8.4 × 10^2 CFU g^{-1}) and actinomycetes (25.8 × 10^3 CFU g^{-1}). The combination of FYM, biofertilizers and vermiwash likely created a nutrient-rich environment that sustained microbial communities. In contrast, T8 (Absolute control) exhibited the lowest microbial counts (bacteria: 18.8 × 10^5 CFU g^{-1}, fungi: 5.4 × 10^2 CFU g^{-1}, actinomycetes: 17.8 × 10^3 CFU g^{-1}), significantly lower than the organically treated plots. The absence of organic inputs likely led to reduced microbial proliferation due to limited nutrient availability and poor organic matter inputs, restricting microbial diversity and enzymatic activity.

The soil biomass carbon and dehydrogenase activity were significantly impacted under the influence of treatment-based inputs (Fig. 4). Soil biomass carbon (132.8 µg g^{-1} soil) and dehydrogenase activity (4.8 µg TPF g^{-1} soil h^{-1}) were highest with the conjunctive application of biofertilizers, vermicompost and vermiwash (T7). Though T7 was found to be at parity with treatments comprising of T4 (FYM), T5 (combination of FYM with *Rhizobium*) and T6 (Biofertilizer in combination with FYM and vermiwash). However, the treatment devoid of organic inputs (T8) had the lowest mean microbial biomass carbon and dehydrogenase activity. The better performance of treatments with biofertilizers and organic amendments can be explained by the multistep mechanism of action of biofertilizers. Biofertilizers, namely *Rhizobium* and Phosphate Solubilizing Bacteria (PSB), increase the availability of nutrients. *Rhizobium* forms nodules with legume roots and fixes atmospheric nitrogen, converting it to plant available forms (Nitrogen fixation), which directly increases nitrogen supply to the crop (28). Similarly, PSB solubilize insoluble soil phosphates into potentially absorbable forms, increasing phosphorus availability (29). Organic amendments like vermicompost, vermiwash and FYM contribute by giving a good substrate for the establishment and proliferation of microbial communities. Organic amendments provide a readily available substrate of carbon, energy, macro and micronutrients, which increase microbial communities (30). The increase in microbial biomass (bacteria, fungi, actinomycetes, etc.) also increases enzymatic activity. Dehydrogenase is one such important enzyme generated by living microbial cells and serves as a good indicator of soil biological activity and health. A higher amount of dehydrogenase in organic treated soils indicates a high level of microbial metabolism and nutrient cycling. These microorganisms have also been shown to release humic substances through their steady-state decomposition of organic materials while promoting soil aggregation and soil physical qualities, improved water retention and improved nutrient retention (31). The integration of organic amendments plays a crucial role in sustaining crop cultivation systems by enhancing soil health, particularly the biological properties such as microbial biomass carbon (32, 33). Furthermore, enzymatic activity such as dehydrogenase, showed significant improvements with the regular application of organic substrates, indicating their role in fostering microbial activity and overall soil fertility (34, 35).

Table 4. Effect of different treatments on the soil microbial population post-harvest

Treatments	Bacteria (x 10^5) (CFU g^{-1})	Fungi (x 10^2) (CFU g^{-1})	Actinomycetes (x 10^3) (CFU g^{-1})
T1	20.3 ± 1.0	6.3 ± 0.1	20.8 ± 1.0
T2	21.4 ± 1.3	6.7 ± 0.3	22.6 ± 1.1
T3	23.5 ± 1.5	7.0 ± 0.2	23.1 ± 0.2
T4	24.4 ± 1.7	7.2 ± 0.4	23.9 ± 1.6
T5	25.9 ± 1.8	7.9 ± 0.4	25.2 ± 0.4
T6	27.0 ± 0.9	8.4 ± 0.5	25.8 ± 0.5
T7	29.8 ± 0.8	8.9 ± 0.5	27.3 ± 1.4
T8	18.8 ± 1.3	5.4 ± 0.2	17.8 ± 0.9
LSD	6.5	2.0	5.5

Effect on economics

Table 5 revealed that applying organic inputs can improve gross and net returns in comparison to no organic input treatment (T8). Gross returns ranged from 58847 to 105252 INR ha^{-1}, whereas net

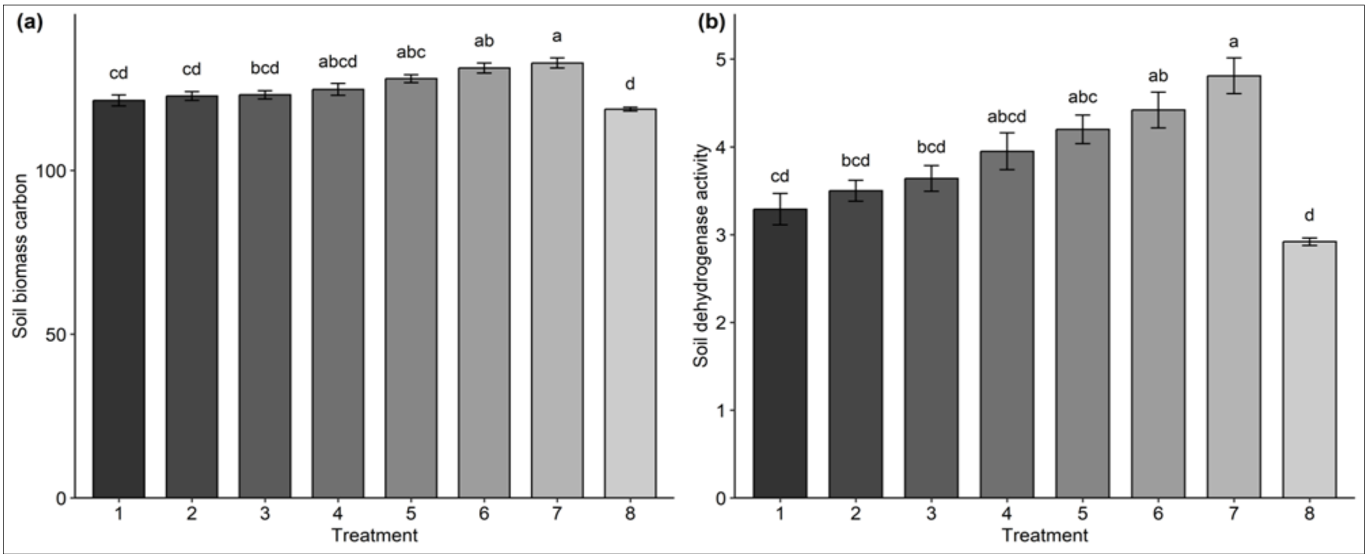

Fig. 4. Effect of different treatments on soil biomass carbon (µg g^{-1} soil) and soil dehydrogenase activity (µg TPF g^{-1} soil hr^{-1}).

Table 5. Effect of different treatments on the economics of black gram

Treatments	Cost of cultivation (INR ha^{-1})	Gross returns (INR ha^{-1})	Net returns (INR ha^{-1})	Benefit-cost ratio
T1	38160	60800	22640	1.59
T2	39710	65125	25415	1.66
T3	41285	70649	29364	1.72
T4	45500	74362	28862	1.65
T5	48600	78752	30152	1.63
T6	48210	88824	40614	1.86
T7	60110	105252	45142	1.76
T8	34000	58847	24847	1.73

returns ranged from 22640 to 45142 INR ha^{-1}. Applying vermicompost in conjunction with biofertilizers and vermiwash (T7) improved the gross and net returns by 46405 and 20295 INR ha^{-1}, respectively, compared to T8. In terms of returns per Indian rupee, a higher value under T6 (combined application of biofertilizer, FYM and vermiwash) (1.86) was mainly because of less cost of inputs involved in their production. Thus, owing to the low cost of inputs and comparable yield with T7 (Table 5), T6 has greater potential to uplift the economic status of marginal farmers.

Conclusion

The findings of this study revealed that the use of bioinoculants (*Rhizobium* + PSB) with vermicompost and vermiwash (T7) increased significant growth parameters. This combination of inputs resulted in fewer number of days to flowering and the crop showed increased height because of using bioinoculants and organic inputs, indicating that the plant had developed better early vegetative stage growth patterns. From this improved growth potential, the crops had also better yield parameters. Ultimately the positive effects on growth and yield in combination gave significantly higher yields of seed and straw, showing the ability of biofertilizers to enhance nutrient management systems in terms of both efficiencies and overall productivity.

In addition to the short term crop performance potential, outcomes of the study indicated significant long-term soil health benefits as well. Soil samples conducted post-harvest consistently indicated large improvements in agricultural chemical and biological properties with organic treatments. Importantly, the treatment incorporating biofertilizers, vermicompost and vermiwash (T7 treatment) produced the highest levels of microbial biomass carbon and enzymatic activity (i.e., dehydrogenase activity).

In addition, the economic assessment further supports the viability of the adopted organic approaches. Organic treatments consistently produced significant profitability and demonstrated greater gross and net revenue. The combined application of biofertilizers, vermicompost and vermiwash had the greatest gross and net revenues, but we found that T6 (biofertilizers, FYM and vermiwash) had a much greater return for each unit invested. Factors such as reduced input costs and higher gross revenues contributed to this economic benefit. Overall, the economic analysis supports the promise integrated organic nutrient management holds to potentially enhance the economic status of marginal farmers with respect to a cost effective, productive and sustainable farming strategy.

Authors' contributions

S and JS performed the experiment and conceptualized design of experiment. S, RS, AV, SS and BBR recorded data. AS and BBR analysed the data. AS prepared visualization using software along with writing main manuscript. RS and BBR helped with literature collection and edited the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

References

1. Singh A, Rana SS, Bala A. Weed management strategies in chickpea (*Cicer arietinum*): a review. Agricultural Reviews 2020;41 (2):153-9. https://doi.org/10.18805/ag.R-1996
2. USDA. National Nutrient Database for Standard Reference Legacy Release-16083. United States Department of Agriculture; 2025. https://web.archive.org/web/20190107124458/https://ndb.nal.usda.gov/ndb/foods/show/16083
3. MOAFW. Selected State/Season-wise Area, Production and Productivity of Urad in India (2021-2022). Ministry of Agriculture and Farmers' Welfare, Government of India, New Delhi; 2023.
4. Bhattacharyya R, Ghosh BN, Mishra PK, Mandal B, Rao CS, Sarkar D, et al. Soil degradation in India: challenges and potential solutions. Sustainability 2015;7(4):3528-70. https://doi.org/10.3390/su7043528
5. Calicioglu O, Flammini A, Bracco S, Bellù L, Sims R. The future challenges of food and agriculture: an integrated analysis of trends and solutions. Sustainability 2019;11(1):222. https://doi.org/10.3390/su11010222
6. Keerthi P, Sharma SK, Chaudhary K. Zero budget natural farming: an introduction. In: Research trends in agriculture sciences. New Delhi: AkiNik Publications; 2018. p. 111-23.
7. Sharma T, Singh J, Kaur N, Shilpa. Effect of organic sources of nutrients on growth and growth indices of cowpea (*Vigna unguiculata*) under mid hill conditions of Himachal Pradesh. Himachal Journal of Agricultural Research 2020;46(2):201-4.
8. Bhardwaj P, Sharma RK. Effect of vermiwash and vermicompost on the growth and productivity of moong dal. Journal of Chemical, Biological and Physical Sciences 2016;6(4):1381-8.
9. Subbiah BV, Asija GL. A rapid procedure for the determination of available nitrogen in soil. Current Science 1956;25:259-60.
10. Olsen SR, Cole CV, Watanabe FS, Dean LA. Estimation of available phosphorus in soils by extraction with sodium bicarbonate. Circular 939, United States Department of Agriculture; 1954. p. 1-19.
11. Metson AJ. Methods of chemical analysis for soil survey samples. New Zealand Soil Bureau 1956;12.
12. Jackson ML. Soil chemical analysis. New Delhi: Prentice Hall of India Pvt. Ltd.; 1973. p. 38-56.
13. Piper CS. Soil and plant analysis. Bombay: Hans Publishers; 1966.
14. Gomez KA, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley & Sons; 1984.
15. Yu HL, Xu BB, Xu GY, Shao W, Gao DT, Si P. Effects of bio-organic fertilizers on apple seedling growth, physiological characteristics and functional diversity of soil microorganisms. China Agric Sci Bull 2022;38:32-8.
16. Ye T, Li Y, Zhang J, Hou W, Zhou W, Lu J, et al. Nitrogen, phosphorus and potassium fertilization affects the flowering time

of rice (*Oryza sativa* L.). Global Ecology and Conservation 2019;20:e00753. https://doi.org/10.1016/j.gecco.2019.e00753

17. Kota AK, Kerketta A, Topno SE, Bahadur V, Tripathi P. Effect of organic fertilizers on growth yield and quality of okra (*Abelmoschus esculentus* L.) Kashi Lalima. The Pharma Innovation Journal 2022;11(5):2301-4.
18. Selim MM. Introduction to the integrated nutrient management strategies and their contribution to yield and soil properties. International Journal of Agronomy 2020;2020:2821678. https://doi.org/10.1155/2020/2821678
19. Singh R, Pratap T, Singh D, Singh G, Singh AK. Effect of phosphorus, sulphur and biofertilizers on growth attributes and yield of chickpea (*Cicer arietinum* L.). Journal of Pharmacognosy and Phytochemistry 2018;7(2):3871-5.
20. Sasidhar P, Singh S, Naidu BA, Chandra Y, Malleswari S, Mohan N. Effect of spacing and biofertilizer on yield and economics of black gram (*Vigna mungo* L.). International Journal of Environment and Climate Change 2022;12(10):114-20. https://doi.org/10.9734/ijecc/2022/v12i1030775
21. Xu ZT, Lu Q, Wu YL, Zhang HJ, Xiao R, Deng HL, et al. Effects of partial replacement of chemical fertilizers with different organic fertilizers on growth dynamics and grain yield of seed corn in Hexi Oasis. Agric Eng 2021;11:129-34.
22. Joshi R, Singh J, Vig AP. Vermicompost as an effective organic fertilizer and biocontrol agent: effect on growth, yield and quality of plants. Reviews in Environmental Science and Biotechnology 2015;14:137-59. https://doi.org/10.1007/s11157-014-9347-1
23. Negi YK, Sajwan P, Uniyal S, Mishra AC. Enhancement in yield and nutritive qualities of strawberry fruits by the application of organic manures and biofertilizers. Scientia Horticulturae 2021;283:110038. https://doi.org/10.1016/j.scienta.2021.110038
24. Zhang F, Shen J, Zhang J, Zuo Y, Li L, Chen X. Rhizosphere processes and management for improving nutrient use efficiency and crop productivity: implications for China. Advances in Agronomy 2010;107:1-32. https://doi.org/10.1016/S0065-2113(10)07001-X
25. Mandal A, Dutta A, Das R, Mukherjee J. Role of intertidal microbial communities in carbon dioxide sequestration and pollutant removal: a review. Marine Pollution Bulletin 2021;170:112626. https://doi.org/10.1016/j.marpolbul.2021.112626
26. Kiyasudeen SK, Ibrahim MH, Quaik S, Ismail SA. Vermicompost, its applications and derivatives. In: Prospects of organic waste management and the significance of earthworms. 2016. p. 201-30. https://doi.org/10.1007/978-3-319-24708-3_9
27. Kumar S, Sindhu SS, Kumar R. Biofertilizers: an ecofriendly technology for nutrient recycling and environmental sustainability. Current Research in Microbial Sciences 2022;3:100094. https://doi.org/10.1016/j.crmicr.2021.100094
28. Kakraliya SK, Singh U, Bohra A, Choudhary KK, Kumar S, Meena RS, et al. Nitrogen and legumes: a meta-analysis. In: Legumes for soil health and sustainable management. Singapore: Springer; 2018. p. 277-314. https://doi.org/10.1007/978-981-13-0253-4_9
29. Emami-Karvani Z, Chitsaz-Esfahani Z. Phosphorus solubilization: mechanisms, recent advancement and future challenge. In: Soil microbiomes for sustainable agriculture: functional annotation. Cham: Springer; 2021. p. 85-131. https://doi.org/10.1007/978-3-030-73507-4_4
30. Bamdad H, Papari S, Lazarovits G, Berruti F. Soil amendments for sustainable agriculture: microbial organic fertilizers. Soil Use and Management 2022;38(1):94-120. https://doi.org/10.1111/sum.12762
31. Mohammadi K, Heidari G, Khalesro S, Sohrabi Y. Soil management, microorganisms and organic matter interactions: a review. African Journal of Biotechnology 2011;10(86):19840. https://doi.org/10.5897/AJBX11.006
32. Choudhary R, Sharma RP, Rana N, Dev P, Sharma GD, Kumar R. Effect of natural farming on yield performances, soil health and nutrient uptake in wheat+gram intercropping system in sub-temperate regions of Himachal Pradesh. Journal of Crop and Weed 2022;18:1-8. https://doi.org/10.22271/09746315.2022.v18.i2.1566
33. Gupta A, Singh UB, Sahu PK, Paul S, Kumar A, Malviya D, et al. Linking soil microbial diversity to modern agriculture practices: a review. International Journal of Environmental Research and Public Health 2022;19(5):3141. https://doi.org/10.3390/ijerph19053141
34. Kumari M, Sheoran S, Prakash D, Yadav DB, Yadav PK, Jat MK. Long-term application of organic manures and chemical fertilizers improve the organic carbon and microbiological properties of soil under pearl millet-wheat cropping system in North-Western India. Heliyon 2024;10(3). https://doi.org/10.1016/j.heliyon.2024.e25333
35. Sharma T, Singh J, Madaik S, Kumar P, Singh A, Rana BB, et al. Organic input incorporation for enhancing sustainability and economic viability of cowpea in North-Western Himalayan region. Frontiers in Agronomy 2024;6:1458603. https://doi.org/10.3389/fagro.2024.1458603

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc
See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

Publisher information: Plant Science Today is published by HORIZON e-Publishing Group with support from Empirion Publishers Private Limited, Thiruvananthapuram, India.