Plant Archives Vol. 26, Supplement 2, 2026 pp.3366-3376 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.428

EFFECT OF BIO COMPOST AND ORGANIC LIQUID FORMULATIONS ON SOIL FERTILITY, PRODUCTIVITY AND PHOSPHORUS AVAILABILITY IN GREEN GRAM (*Vigna radiata* L.)

Marvaniya Kalindri S.[1], Sonal Tripathi[1], Aditi Chauhan[2*], Narendra Singh[1], Drashti Patel[3] and Viral Patel[4]

[1]Department of Soil Science, Navsari Agricultural University, Navsari (Gujarat) 396450, India
[2]Food Quality Testing Laboratory, Navsari Agricultural University, Navsari (Gujarat) 396450, India
[3]Centre for Oilseed Research, Sardar Krushinagar Dantiwada Agricultural University, Dantiwada (Gujarat) 385506, India
[4]College of Agriculture, Waghai, Navsari Agricultural University, Navsari (Gujarat) 394730, India
*Corresponding author E-mail: aditi@nau.in

(Date of Receiving : 23-05-2026; Date of Revision : 05-07-2026; Date of Acceptance : 25-07-2026)

ABSTRACT

A field experiment was conducted during summer 2024 at the Research Farm of Navsari Agricultural University, Navsari, to investigate the impact of organic liquid formulations (Gliricidia leaf extract G-amrut, Jeevamrut, and Vermibedwash) and biocompost, combined with phosphorus fertilization, on soil health and green gram performance. The experiment followed a randomized block design with eight treatments and three replications. Results revealed that application of 100% RDN (20 kg N ha^{-1}) through biocompost + 500 L ha^{-1} Vermibedwash produced significantly higher plant height, dry matter accumulation, seed and stover yield, and crude protein yield compared to other treatments. This treatment improved available soil nitrogen and phosphorus by 16.5% and 17.6%, respectively, and enhanced total microbial count by 25–30% over 100% RDN alone. Correlation analysis indicated that seed yield was positively associated with vegetative growth, nutrient availability, and microbial biomass. The study demonstrates the synergistic role of biocompost and organic liquid formulations in promoting soil fertility, crop productivity, and sustainable green gram cultivation.

Keywords **:** Biocompost, Gliricidia leaf extract, Jeevamrut, Soil health, Vermibedwash.

Introduction

Pulses are a valuable source of protein and essential nutrients, including carbohydrates, dietary fiber, vitamins, and minerals, and play a pivotal role in ensuring food security and promoting sustainable agriculture (Didinger and Thompson, 2021; Grden and Jakubczyk, 2023; Langyan *et al*., 2022; Parca *et al*., 2018). Among pulses, green gram (*Vigna radiata* L.), commonly known as mung bean, is an important short-duration legume crop owing to its low water requirement, adaptability to diverse agroclimatic conditions, and high nutritional value (Sarma and Saikia, 2013). The seeds contain approximately 25% protein, 56% carbohydrates, 4% fiber, and 3.5% minerals, making green gram an important source of dietary protein while providing economic benefits to farmers (Dahiya *et al*., 2014; Hou *et al*., 2019; Nair *et al*., 2013; Sandhu and Singh, 2020).

Modern agriculture faces serious challenges, including soil degradation, nutrient depletion, and environmental pollution caused by the excessive use of chemical fertilizers and the declining application of organic amendments (Al-Suhaibani *et al*., 2020; Gupta *et al*., 2022). Integrated nutrient management (INM) offers a sustainable approach to maintaining crop productivity while improving soil health (Dhaliwal *et al*., 2021; Patra *et al*., 2020). The integration of organic nutrient sources such as biocompost with liquid organic formulations (LOFs), including Gliricidia leaf extract (G-amrut), Jeevamrut, and Vermibedwash, has emerged as an effective strategy for reducing dependence on chemical fertilizers (Ali *et al*., 2025; Chatterjee *et al*., 2017; Imran, 2024).

Biocompost, produced from press mud and distillery spent wash, is a rich source of macro- and micronutrients, humic substances, and organic carbon that enhances soil fertility and microbial biomass (Goldan *et al*., 2023; Mehta *et al*., 2024). G-amrut, prepared from *Gliricidia sepium* leaves, contains plant growth-promoting substances such as auxins, cytokinins, phenolics, and natural enzymes that stimulate root development and nutrient uptake (Nath and Tuteja, 2015). Jeevamrut supplies beneficial microorganisms capable of atmospheric nitrogen fixation and phosphorus solubilization (Chen *et al*., 2024; Tahat *et al*., 2020). Vermibedwash is rich in soluble nutrients, vitamins, enzymes, and plant growth regulators that improve plant growth and development. These organic inputs improve soil biological activity, nutrient availability, and crop productivity while enhancing soil organic carbon and microbial populations (Joshi *et al*., 2014; Oyege and Balaji Bhaskar, 2023; Pathma and Sakthivel, 2012; Yatoo *et al*., 2022). Improved nutrient availability and soil physical properties ultimately promote vegetative growth, pod development, and grain yield (Jouquet *et al*., 2011; Rehman *et al*., 2023; Rey *et al*., 2024).

Although several studies have reported the beneficial effects of organic nutrient sources on pulse crops, limited information is available regarding the combined application of biocompost, phosphorus fertilization, and different liquid organic formulations on soil health, microbial activity, nutrient availability, and green gram productivity. Therefore, the present study was undertaken to evaluate the effect of integrating biocompost, single super phosphate (SSP), and different liquid organic formulations (G-amrut, Jeevamrut, and Vermibedwash) on soil properties, growth, yield, quality, and microbial population of green gram.

Materials and Methods

Experimental Site and Soil Characteristics

A field experiment was conducted during the summer season of 2024 at the College Farm, Navsari Agricultural University, Navsari, Gujarat, India (20°57′ N latitude and 72°54′ E longitude, at an altitude of 10 m above mean sea level). The experimental site is situated in the South Gujarat agro-climatic zone and is characterized by a tropical humid climate. Before sowing, composite surface soil samples (0–15 cm depth) were collected from the experimental field and analysed using standard analytical procedures. The soil contained 15.20% sand, 25.12% silt, and 59.68% clay and was classified as clay according to the USDA textural classification (USDA, 1951). The initial soil had a pH of 7.24 and an electrical conductivity (EC) of 1.82 dS m^{-1}, determined in a 1:2.5 soil-water suspension using a digital pH meter and conductivity meter, respectively (Jackson, 1973). Organic carbon content (0.45%) was estimated by the Walkley and Black wet oxidation method (Jackson, 1973). Available nitrogen (240.60 kg ha^{-1}) was determined by the alkaline potassium permanganate ($KMnO_4$) method (Subbiah and Asija, 1956), available phosphorus (45.78 kg ha^{-1}) by Olsen's sodium bicarbonate extraction method followed by spectrophotometric determination, and available potassium (497.42 kg ha^{-1}) by extraction with neutral 1 N ammonium acetate and estimation using a flame photometer (Jackson, 1973). DTPA-extractable micronutrients, namely iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu), were determined using the method described by Lindsay and Norvell (1978) and quantified using an atomic absorption spectrophotometer. The initial fungal and bacterial populations of the soil were 33.15 × 10^5 and 15.42 × 10^7 cfu g^{-1} soil, respectively, as determined by the serial dilution plate count technique (Agarwal and Hasija, 1986).

Experimental Details

The experiment was laid out in a Randomized Block Design (RBD) with three replications comprising eight nutrient management treatments, viz., T_1: Absolute control; T_2: 100% recommended dose of nitrogen (RDN) through biocompost + 40 kg P_2O_5 ha^{-1} through single super phosphate (SSP); T_3: 100% RDN + G-amrut @ 500 L ha^{-1}; T_4: 75% RDN + G-amrut @ 500 L ha^{-1}; T_5: 100% RDN + Jeevamrut @ 500 L ha^{-1}; T_6: 75% RDN + Jeevamrut @ 500 L ha^{-1}; T_7: 100% RDN + Vermibedwash @ 500 L ha^{-1}; and T_8: 75% RDN + Vermibedwash @ 500 L ha^{-1}. The recommended fertilizer dose for green gram was 20 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}. Nitrogen was supplied through biocompost according to the respective treatments, whereas phosphorus was applied uniformly through single super phosphate (16% P_2O_5) in all fertilized treatments. The liquid organic formulations (G-amrut, Jeevamrut and Vermibedwash) were applied as soil drenching at the rate of 500 L ha^{-1} at sowing, 20 days after sowing (DAS) and 40 DAS.

The chemical composition of the bio-compost and various liquid organic sources used in the study were analyzed on a dry weight basis. The bio-compost had a moisture content of 51.50% and contained 1.58% total nitrogen (N), 0.96% total phosphorus (P_2O_5), and 0.45% total potassium (K_2O) (Jackson 1973). Among the liquid organic sources, Jeevamrut, G-amrut, and Vermibedwash contained 0.10 %, 0.124 %, and 0.120% total N; 0.01%, 0.061%, and 0.042% total P, and 0.06 %, 0.214 %, and 0.127% total K, respectively

(Jackson, 1973). Micronutrient analysis revealed that Fe, Mn, Zn, and Cu concentrations varied among the sources Jeevamrut, G-amrut, and Vermibedwash, with Fe 454.70, 99.63 and 0.06 to mg kg^{-1}, Mn 4.83, 2.20 and 0.60 mg kg^{-1}, Zn 14.24, 0.41 and 0.02 to mg kg^{-1}, and Cu 6.1, 0.14 and 0.01 mg kg^{-1} respectively, determined after diacid digestion (4 HNO_3:10 $HClO_4$) followed by atomic absorption spectrophotometry (Lindsay and Norvell, 1978). The green gram variety GM-6 was used in the present investigation. The crop was sown manually on 16 February 2024 at a spacing of 30 cm × 10 cm (row-to-row × plant-to-plant). The gross plot size was 16.8 m^2, whereas the net plot size was 13.68 m^2, obtained after excluding the two outermost border rows and border plants from all sides to eliminate border effects.

Observations Recorded

Growth, yield, and yield-attributing observations were recorded from representative plants in each treatment. Plant height was measured from five randomly selected plants in the net plot at 30 and 60 days after sowing (DAS) and at harvest. The number of branches per plant was recorded at harvest. For dry matter accumulation, three randomly selected plants from the second row of each net plot were harvested at crop maturity. The aboveground plant samples were chopped into small pieces, sun-dried for 2–3 days, and subsequently oven-dried at 65 ± 5°C until a constant weight was attained. The average dry matter accumulation was recorded and expressed as g $plant^{-1}$. The crop was harvested manually using sickles when approximately 80% of the pods had attained maturity. Five randomly selected plants from each net plot were used to record the number of pods per plant and the number of seeds per pod. Seed, stover, and biological yields (kg ha^{-1}) were determined from the produce harvested from the net plot area. The harvest index (%) was calculated as the ratio of seed yield to biological yield multiplied by 100. After harvest, the soil samples were again analyzed using the same methods as mentioned earlier to assess post-harvest changes in soil fertility.

Statistical Analysis

The data recorded for various parameters were subjected to statistical analysis following the procedure described by Panse and Sukhatme (1985). The significance of treatment effects was tested using analysis of variance (ANOVA). Whenever the treatment effects were found to be significant, the treatment means were compared using the Standard Error of Mean (SEm±) and Critical Difference (CD) at the 5% level of significance. Duncan's Multiple Range Test (DMRT) (Duncan, 1955) was also performed for multiple comparisons among treatment means. Correlation analysis was carried out to determine the relationship between seed yield and yield-attributing characters. The correlation matrix was illustrated as a correlogram using OriginPro 2024 (OriginLab Corporation, USA).

Results and Discussion

Growth, yield attributing characters and crude protein content in green gram

The application of different nutrient management treatments significantly influenced the growth, yield attributes and crude protein content of green gram (Tables 1 and 2; Fig. 1). Among the treatments, T_7 (100% RDN + Vermibedwash @ 500 L ha^{-1}) recorded the highest plant height at 60 DAS (43.42 cm) and at harvest (43.75 cm), along with the maximum dry matter accumulation (41.67 g $plant^{-1}$), representing increases of 11.56%, 4.53% and 33.26%, respectively, over T_2 (100% RDN). Plant height at 30 DAS and the number of branches per plant did not differ significantly among the treatments, although T_7 recorded the highest values of 13.76 cm and 7.42, respectively. The improved growth under T_7 may be attributed to the continuous supply of macro- and micronutrients, plant growth regulators, enzymes and beneficial microorganisms through Vermibedwash, which enhanced nutrient uptake, photosynthetic activity, cell division and dry matter accumulation. Similar findings have been reported by Chaurasia *et al.* (2024) and Dineshkumar *et al*. (2020). Yield-attributing characters and yield were also significantly influenced by nutrient management practices (Table 2). Treatment T_7 produced the highest number of pods per plant (24.23) and seeds per pod (11.75), resulting in significantly higher seed yield (1158.27 kg ha^{-1}) and stover yield (2471.29 kg ha^{-1}), which were 44.13% and 38.87% higher, respectively, than those recorded under T_2. However, the harvest index was not significantly affected by the treatments. The superior yield obtained with Vermibedwash application may be attributed to improved nutrient availability throughout the crop growth period, resulting in enhanced photosynthetic efficiency, greater dry matter production and efficient translocation of assimilates towards reproductive organs. In addition, Vermibedwash supplies beneficial microorganisms, phytohormones and enzymes that promote nutrient uptake, plant metabolism and biomass production. Similar results have been reported by Gao *et al*. (2020), Iqbal *et al*. (2019), Batool (2024) and Khan *et al*. (2024).

Crude protein content and crude protein yield were also significantly influenced by the nutrient management treatments (Fig. 1). Treatment T_7 recorded the highest crude protein content (22.92%) and crude protein yield (266.09 kg ha^{-1}). The enhanced protein content may be attributed to the balanced supply of nitrogen and other essential nutrients together with the presence of humic substances, vitamins, enzymes and plant growth-promoting compounds in Vermibedwash, which improved nitrogen assimilation and protein biosynthesis. These findings are in agreement with those reported by Nurdiawati *et al*. (2019), Rupani *et al*. (2018) and Hoque *et al*. (2022).

Soil Parameters

Physicochemical properties of soils in green gram

Physicochemical properties of soil

The post-harvest physicochemical properties of the soil are presented in Table 3. Soil pH ranged from 7.36 to 7.49, indicating neutral to slightly alkaline soil conditions. The highest pH (7.49) was recorded in T_2 (100% RDN), whereas the lowest value (7.36) was observed in T_1 (control) and T_3 (100% RDN + G-amrut). However, the differences among treatments were statistically non-significant, indicating that the nutrient management practices had no appreciable effect on soil pH during the experimental period. Similarly, soil electrical conductivity (EC) ranged from 1.47 to 1.91 dS m^{-1}, with the highest value recorded in T_1 (control) and the lowest in T_8 (75% RDN + Vermibedwash). Organic carbon content varied from 0.56 to 0.65%, with relatively higher values observed in treatments receiving organic amendments. However, the differences in EC and organic carbon among the treatments were also statistically non-significant (Table 3).

The non-significant changes in soil pH, EC and organic carbon may be attributed to the short duration of the experiment and the inherent buffering capacity of the soil, which limited rapid changes in physicochemical properties. The slight increase in organic carbon under organic treatments could be attributed to the addition of organic residues and enhanced microbial activity following the application of biocompost and liquid organic formulations. Similar findings have been reported by Behera *et al*. (2016), Holatko *et al*. (2022), Pittarello *et al*. (2021) and Gautam *et al*. (2021).

Available N, P_2O_5, K_2O, DTPA-extractable micronutrients (Fe, Mn, Zn and Cu), and total microbial population

The effect of different organic liquid formulations along with recommended nitrogen dose on soil available nutrients is presented in Table 4. The available nitrogen content was significantly influenced by the treatments. The highest available N (336.70 kg ha^{-1}) was recorded with the application of 100% RDN + 500 L ha^{-1} Vermibedwash (T_7), showing a 16.54% increase over 100% RDN alone (T_2). The treatment T_3 (100% RDN + 500 L ha^{-1} G-amrut) also improved available N (314.59 kg ha^{-1}) by 8.89% compared with T_2. The lowest available N was recorded under control (T_1) (252.22 kg ha^{-1}). The enhanced nitrogen availability with organic liquid formulations may be attributed to improved microbial activity, faster mineralization of organic matter and favourable C:N ratio, which promoted nitrogen transformation and availability in soil (Suyal *et al*., 2021; Toor *et al*., 2024).

The available phosphorus content was significantly improved by organic liquid applications. The maximum available P_2O_5 (52.29 kg ha^{-1}) was observed in T_7, showing a 17.56% increase over control. Treatments T_3 and T_5 (100% RDN + 500 L ha^{-1} Jeevamrut) recorded 47.66 and 47.21 kg ha^{-1} available P_2O_5, respectively, with corresponding increases of 7.15 and 6.14% over T_2. The enhancement in phosphorus availability may be associated with the release of organic acids during decomposition, which reduce phosphorus fixation through chelation of Fe and Al ions. Additionally, increased microbial activity facilitates phosphorus solubilization and mineralization, thereby improving its availability in soil (Huang and Imran, 2023; Mwende Muindi, 2019; Yadav and Yadav, 2024).

The available K_2O content ranged from 506.78 to 634.59 kg ha^{-1}; however, the differences among treatments were statistically non-significant. The highest available K_2O was recorded under T_7, while the lowest was observed in the control treatment. The slight improvement in available potassium with Vermibedwash application may be due to the release of potassium from decomposing organic matter and enhanced microbial-mediated mineral weathering. Similar observations regarding the role of organic inputs in improving potassium availability have been reported by Jouquet *et al*. (2011), Mondal *et al*. (2016), Schröder *et al*. (2021), and Singh *et al*. (2019).

The application of organic liquid formulations significantly influenced DTPA-extractable Fe and Mn, whereas Zn and Cu contents remained unaffected (Fig. 3). The highest DTPA-extractable Fe (7.44 mg kg^{-1}) and Mn (15.14 mg kg^{-1}) were recorded in T_7, representing increases of 28.72 and 12.06%, respectively, over T_2. Treatment T_3 also showed improvement in Fe and Mn availability compared with other treatments. The lowest micronutrient availability was observed in the control treatment. The increased availability of Fe and Mn under Vermibedwash application could be attributed to enhanced microbial activity and production of organic acids during organic matter decomposition, which improve micronutrient solubilization. Furthermore, organic compounds present in liquid organic formulations may form soluble complexes with micronutrients, increasing their extractability and availability in soil (Li *et al*., 2012; Wang *et al*., 2018; Rengel, 2015). Overall, the application of 100% RDN along with Vermibedwash (500 L ha^{-1}) proved effective in improving soil nutrient availability, particularly nitrogen, phosphorus, Fe and Mn, by enhancing nutrient mineralization and biological activity in the rhizosphere.

Total microbial population

The influence of different organic liquid formulations along with nitrogen fertilization on soil microbial population is presented in Table 5. The fungal population significantly varied among treatments and ranged from 48.12 × 10^5 to 100.76 × 10^5 cfu g^{-1} soil. The highest fungal population was recorded under T_7 (100% RDN + 500 L ha^{-1} Vermibedwash), showing a 25.44% increase over T_2 (100% RDN) and remained statistically comparable with T_3 (100% RDN + 500 L ha^{-1} G-amrut). The lowest fungal population was observed in the control treatment (T1), which showed a 40.09% reduction compared with T_2.

Similarly, bacterial population showed significant variation among treatments, ranging from 20.23 × 10^7 to 39.64 × 10^7 cfu g^{-1} soil. The maximum bacterial population was recorded in T_7, followed by T_3, whereas the minimum population was observed under T_1, showing a 38.10% reduction compared with T_2. Treatments receiving 75% RDN along with organic formulations (T_4, T_6 and T_8) recorded moderate microbial populations compared with treatments receiving 100% RDN with organic inputs. The increased fungal and bacterial populations under organic liquid formulations may be attributed to the addition of readily available carbon sources, organic compounds and beneficial microorganisms present in Vermibedwash, G-amrut and Jeevamrut. These inputs create a favourable rhizosphere environment by stimulating microbial growth, enhancing nutrient cycling and improving biological activity in soil. Similar results were reported by Khan *et al.* (2024), Suyal *et al*. (2021) and Wu *et al.* (2024), who observed increased microbial abundance following organic amendments. Organic inputs serve as substrates for microbial proliferation and contribute to the development of a diverse and active soil microbial community (Lupatini *et al*., 2017; Park *et al*., 2020; Tahat *et al*., 2024).

Correlation study among soil characteristics and yield-related traits

The correlation analysis between soil characteristics and yield-related traits revealed significant positive relationships between grain yield and various growth, yield, and quality parameters of mung bean (Fig. 4). Vegetative traits, including plant height at 30 DAS, 60 DAS and harvest stage, along with the number of branches per plant, showed a strong positive association with grain yield, indicating the importance of vigorous vegetative growth for higher reproductive performance. Similarly, yield attributes such as pods per plant, seeds per pod, and dry matter accumulation exhibited a close relationship with grain yield, confirming their significant contribution towards productivity. Seed crude protein content also showed a positive association with yield, suggesting that balanced nutrient management improves both yield performance and nutritional quality.

The correlation matrix further indicated that soil available N, P_2O_5, K_2O, DTPA-extractable Fe and Mn, organic carbon content, and microbial populations (fungi and bacteria) were positively associated with mung bean grain yield. The positive contribution of macronutrients may be attributed to their essential roles in vegetative growth, root development, photosynthetic activity, and grain filling. Similarly, Fe and Mn play important roles in chlorophyll synthesis, enzyme activation, and metabolic processes, thereby improving plant growth and yield formation (Favero *et al*., 2021). Higher microbial activity enhances nutrient mineralization, nutrient cycling, soil biological health, and plant–microbe interactions, which collectively support crop productivity (Bilal *et al*., 2021).

In contrast, soil pH, electrical conductivity (EC), and available Zn and Cu did not show significant correlations with grain yield, indicating that their levels remained within the optimum range and did not impose any nutritional limitations under the experimental conditions (Baroowa *et al*., 2016; Dineshkumar *et al*., 2020). Similar relationships between soil properties and yield-related traits have also been reported in different crops (Xu *et al*., 2017).

Conclusion

Applying 100 % RDN (20 kg N ha^{-1}) through bio-compost along with Vermibedwash (at sowing, 20 and

40 DAS) and 40 kg ha^{-1} P_2O_5 supplied through single super phosphate (16% P_2O_5) significantly enhanced growth and yield of summer green gram and improved soil chemical and biological properties. The findings suggest that replacing 100% RDN through bio-compost supplemented with Vermibedwash can serve as a viable and sustainable approach for improving crop performance and soil health. In summary, seed yield was strongly influenced by nutrient-rich and biologically active soils, whereas soil pH, EC, Zn, and Cu, although important indicators of soil quality, did not significantly affect seed performance under the experimental conditions. In the absence of Vermibedwash, similar benefits may be achieved using G-amrut or Jeevamrut under the same management practices, providing an effective and sustainable nutrient management strategy. Future studies should focus on nutrient leaching dynamics, particularly in vulnerable agroecosystems, and evaluate produce quality along with practical challenges associated with farmer adoption of these practices.

Table 1: Effect of different treatments on plant height (cm), number of branches per plant at harvest and dry matter (g plant^{-1}) of green gram

Treatments	Periodical plant height (cm)			Number of branches per plant at harvest	Dry matter per plant (g plant^{-1})
	30 DAS	60 DAS	At harvest		
T_1 (Absolute control)	12.10	32.9^{c}	33.46^{b}	6.67	23.47^{f}
T_2 (100 % RDN)	10.82	39.21^{ab}	41.54^{a}	6.83	31.27^{cd}
T_3 (100% RDN + 500 l/ha G-amrut)	13.38	41.93^{ab}	43.27^{a}	7.25	38.77^{ab}
T_4 (75% RDN + 500 l/ha G-amrut)	12.92	37.39^{bc}	39.36^{ab}	6.67	27.8^{def}
T_5 (100% RDN + 500 l/ha Jeevamrut)	12.79	40.63^{ab}	42.42^{a}	7.17	35.23^{bc}
T_6 (75% RDN + 500 l/ha Jeevamrut)	14.10	35.82^{bc}	37.94^{ab}	6.25	25.57^{ef}
T_7 (100% RDN +500 l/ha Vermi bed wash)	13.76	43.75^{a}	43.42^{a}	7.42	41.67^{a}
T_8 (75% RDN + 500 l/ha Vermi bed wash)	11.56	38.38^{abc}	39.91^{ab}	7.08	29.07^{de}
SEm ±	0.72	1.85	1.91	0.46	1.51
CD at 5 %	NS	5.61	5.8	NS	4.59

Table 2: Effect of different treatments on plant height (cm), number of branches per plant at harvest and dry matter (g/plant) of green gram

Treatments	Number of pods per plant	Number of seeds per pod	Yield (kg ha^{-1})		Harvest Index (%)
			Seed	Stover	
T_1 (Absolute control)	18.85^{c}	6.83^{e}	803.6^{b}	1779.53^{b}	31.14
T_2 (100 % RDN)	21.64^{abc}	9.43^{bc}	950.21^{b}	2325.52^{a}	28.95
T_3 (100% RDN + 500 L ha^{-1} G-amrut)	22.74^{ab}	9.85^{b}	996.57^{ab}	2445.12^{a}	28.94
T_4 (75% RDN + 500 L ha^{-1} G-amrut)	20.55^{bc}	8.23^{cd}	919.55^{b}	2188.71^{a}	29.58
T_5 (100% RDN + 500 L ha^{-1} Jeevamrut)	21.98^{ab}	9.67^{b}	982.31^{ab}	2384.97^{a}	29.22
T_6 (75% RDN + 500 L ha^{-1} Jeevamrut)	20.29^{bc}	7.93^{de}	841.47^{b}	2165.98^{a}	27.86
T_7 (100% RDN +500 L ha^{-1} Vermi bed wash)	24.23^{a}	11.75^{a}	1158.27^{a}	2471.29^{a}	31.88
T_8 (75% RDN + 500 L ha^{-1} Vermi bed wash)	21.02^{bc}	8.92^{bcd}	935.8^{b}	2257.01^{a}	29.42
SEm ±	0.88	0.41	61.06	99.03	1.8
CD at 5 %	2.67	1.24	185.22	300.36	NS

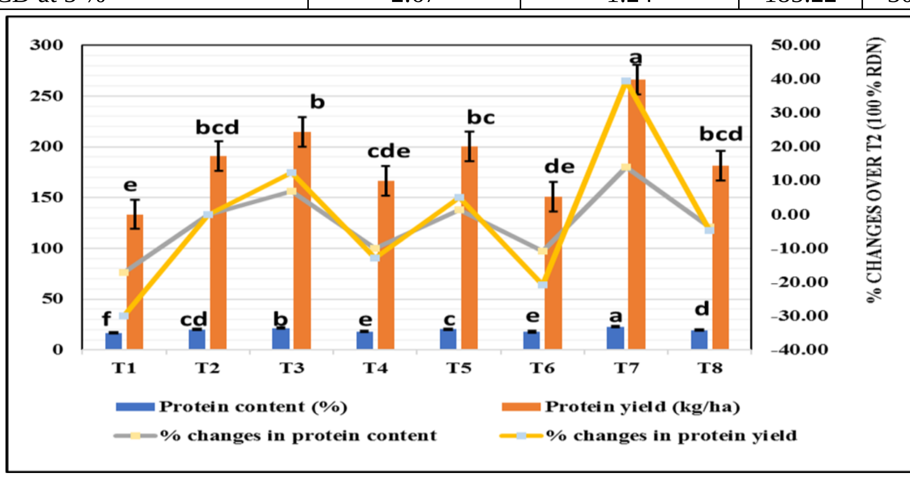

Fig. 1 : Effect of different treatments on crude protein content and crude protein yield of green gram

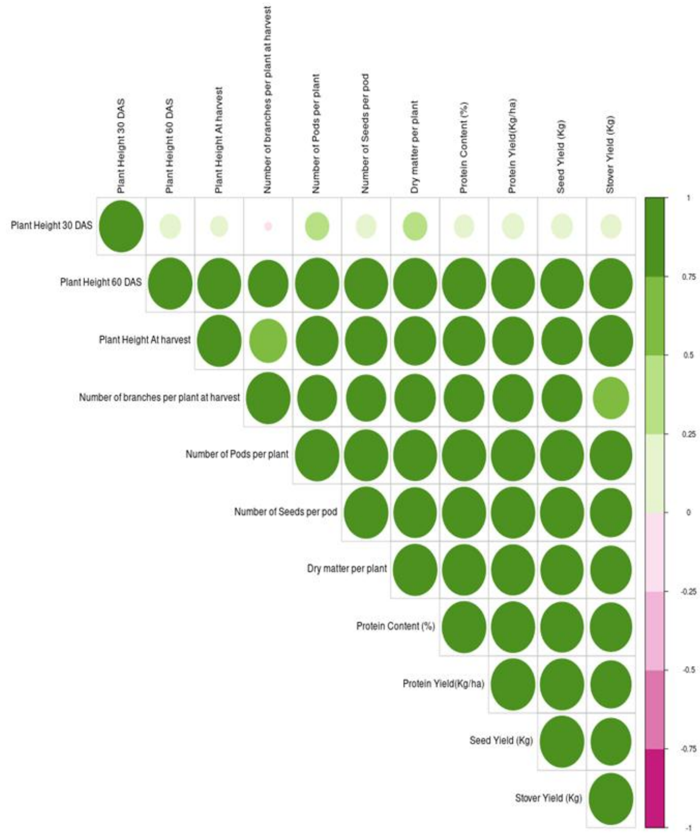

Fig. 2 : Correlation between yield attributes and grain yield of green gram

Table 3 : Effect of different treatments on pH, EC and OC content of soil after harvest

Treatments	pH (1:2.5)	EC (1:2.5) (dS/m)	OC (%)
T_1 (Absolute control)	7.36	1.91	0.56
T_2 (100 % RDN)	7.49	1.74	0.61
T_3 (100% RDN + 500 L ha^{-1} G-amrut)	7.36	1.89	0.64
T_4 (75% RDN + 500 L ha^{-1} G-amrut)	7.38	1.75	0.60
T_5 (100% RDN + 500 L ha^{-1} Jeevamrut)	7.42	1.63	0.64
T_6 (75% RDN + 500 L ha^{-1} Jeevamrut)	7.45	1.77	0.59
T_7 (100% RDN +500 L ha^{-1} Vermi bed wash)	7.41	1.70	0.65
T_8 (75% RDN + 500 L ha^{-1} Vermi bed wash)	7.38	1.47	0.61
SEm ±	0.07	0.09	0.03
CD at 5 %	NS	NS	NS
CV (%)	1.55	9.07	7.48
Initial	7.24	1.82	0.45

Table 4 : Effect of different treatments on available N, P_2O_5, K_2O status in soil after harvest of green gram

Treatments	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})
T_1 (Absolute control)	252.22^{d}	36.44^{d}	506.78
T_2 (100 % RDN)	288.91^{c}	44.48^{bc}	583.82
T_3 (100% RDN + 500 L ha^{-1} G-amrut)	314.59^{b}	47.66^{b}	596.47
T_4 (75% RDN + 500 L ha^{-1} G-amrut)	264.84^{d}	43.45^{bc}	562.28
T_5 (100% RDN + 500 L ha^{-1} Jeevamrut)	300.09^{bc}	47.21^{b}	589.87
T_6 (75% RDN + 500 L ha^{-1} Jeevamrut)	257.00^{d}	40.12^{cd}	558.29
T_7 (100% RDN +500 L ha^{-1} Vermi bed wash)	336.70^{a}	52.29^{a}	634.59
T_8 (75% RDN + 500 L ha^{-1} Vermi bed wash)	284.61^{c}	44.02^{bc}	575.38
SEm ±	5.26	1.50	22.77
CD at 5 %	15.95	4.54	NS
CV (%)	3.17	5.83	6.85
Initial	240.60	45.78	497.42

Mean followed by same letter\s within each column are not significantly different from each other at 5% level of significance.

	SEm ±	CD at 5 %	CV (%)
Fe (mg/kg)	0.3	0.91	9.37
Mn(mg/kg)	0.53	1.6	7.03
Zn (mg/kg)	0.06	NS	9.76
Cu (mg/kg)	0.22	N.S.	7

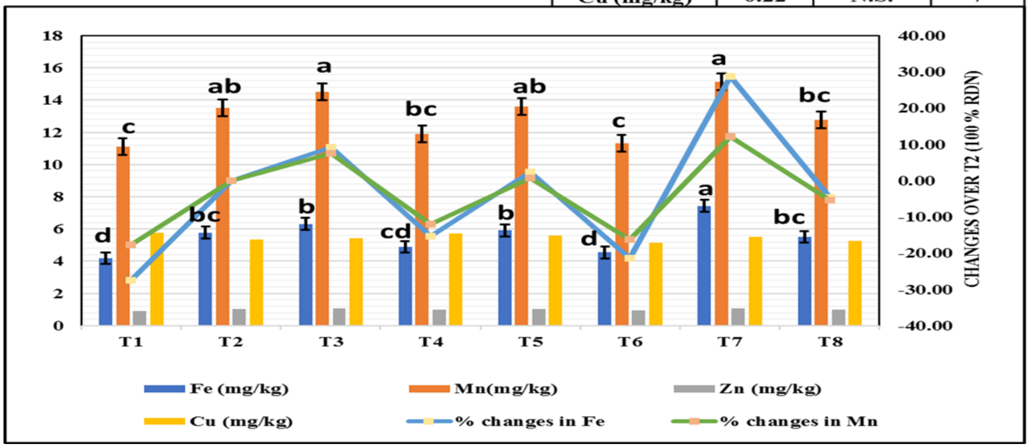

Fig. 3 : Effect of different treatments on DTPA extractable Fe, Mn, Zn, Cu status in soil after harvest of green gram

Table 5 : Effect of different treatment on total microbial count in soil after harvest of green gram

Treatments	Total Fungi ($\times 10^5$ (cfu/gm)	Total Bacteria ($\times 10^7$ (cfu/gm)
T_1 (Absolute control)	48.12^{f}	20.23^{d}
T_2 (100 % RDN)	80.32^{bcd}	32.68^{b}
T_3 (100% RDN + 500 L ha^{-1} G-amrut)	96.03^{ab}	37.25^{ab}
T_4 (75% RDN + 500 L ha^{-1} G-amrut)	67.13^{de}	25.25^{cd}
T_5 (100% RDN + 500 L ha^{-1} Jeevamrut)	87.30^{abc}	34.35^{b}
T_6 (75% RDN + 500 L ha^{-1} Jeevamrut)	57.80^{ef}	23.30^{cd}
T_7 (100% RDN +500 L ha^{-1} Vermi bed wash)	100.76^{a}	39.64^{a}
T_8 (75% RDN + 500 L ha^{-1} Vermi bed wash)	71.90^{cde}	25.88^{c}
SEm ±	5.02	1.51
CD at 5 %	15.24	4.58
CV (%)	11.42	8.77
Initial	33.15	15.42

Mean followed by same letter\s within each column are not significantly different from each other at 5% level of significance.

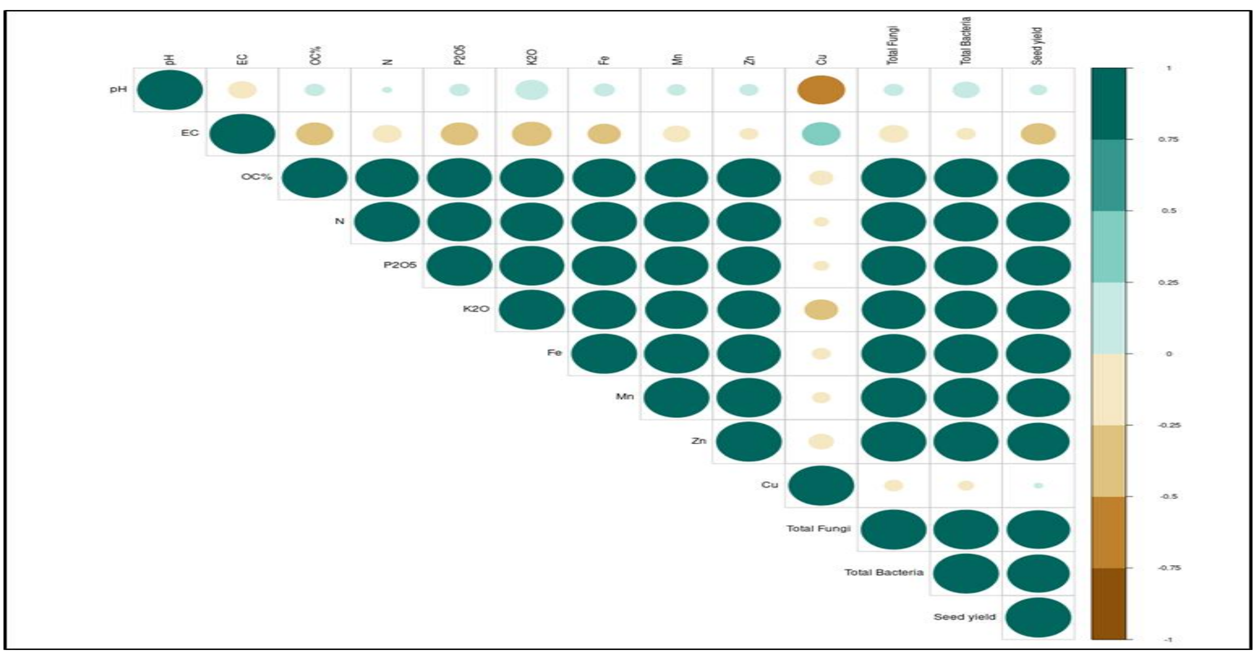

Fig. 4 : Correlation studies of soil parameters and grain yield of green gram

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this manuscript.

References

Agarwal, G.P. and Hasija, S.K. (1986). *Microorganisms in the Laboratory: A Laboratory Guide of Microbiology, Mycology and Plant Pathology*. Print House, Lucknow, India, 155 pp

Ali, A., Jabeen N., Chachar Z., Chachar S., Ahmed S., Ahmed N., Laghari A.A., Sahito Z.A., Farruhbek R. and Yang Z. (2025). The role of biochar in enhancing soil health and interactions with rhizosphere properties and enzyme activities in organic fertilizer substitution. *Front. Plant Sci.*, **16,** 1595208. https://doi.org/10.3389/fpls.2025.1595208

Al-Suhaibani, N., El-Hendawy S., Alderfasi A. and Selim M. (2020). Comparative performance of integrated nutrient management between composted agricultural wastes, chemical fertilizers, and biofertilizers in improving soil quantitative and qualitative properties and crop yields under arid conditions. *Agronomy*, **10(10),** 1503. https://doi.org/10.3390/agronomy10101503

Baroowa, B., Gogoi N. and Farooq M. (2016). Changes in physiological, biochemical and antioxidant enzyme activities of green gram (Vigna radiata L.) genotypes under drought. *Acta Physiol. Plant*., **38(9),** 220. https://doi. org/10.1007/s11738-016-2230-7

Batool, M. (2024). Nutrient management of maize. IntechOpen. https://doi.org/10.5772/intechopen.112484

Behera, S.K., Ramachandrudu K., Prakash C., Mathur R.K., Manorama K., Suresh K., Rao B.N., Harinarayana P. and Shukla A.K. (2016). Spatial variability of some soil properties in oil palm (Elaeis guineensis Jacq.) plantations of the west coastal area of India. *Solid Earth*, **7(3),** 979-993. https://doi.org/10.5194/se-7-979-2016

Bilal, S., Alamri S., Ramzan A., Ashraf I., Sher F., Qamar N., Siddiqui M.H., Hazafa A. and Naeem M. (2021). Comparative effect of inoculation of phosphorus-solubilizing bacteria and phosphorus as sustainable fertilizer on yield and quality of mung bean (*Vigna radiata* L.). *Plants*, **10(10),** 2079. https://doi.org/10.3390/plants10102079

Chatterjee, R., Thirumdasu R.K. and Gajjela S. (2017). Recycling of organic wastes for sustainable soil health and crop growth. *Int. J. Waste Resour*., **7(3),** 296. https://doi.org/10.4172/2252-5211.1000296

Chaurasia, J., Poudel B., Mandal T., Acharya N. and Ghimirey V. (2024). Effect of micronutrients, rhizobium, salicylic acid, and effective microorganisms on plant growth and yield characteristics of green gram [*Vigna radiata* (L.) Wilczek] in Rupandehi, Nepal. *Heliyon*, **10(5),** e26821. https://doi.org/10.1016/j.heliyon.2024.e26821

Chen, Q., Zhong G., Lu Y., An Y. and Song Y. (2024). Soil microorganisms: Their role in enhancing crop nutrition and health. *Diversity*, **16(12),** 734. https://doi.org/10.3390/d16120734

Dahiya, P.K., Linnemann A.R., Van Boekel M.A.J.S., Khetarpaul N., Grewal R.B. and Nout M.J.R. (2014). Mung bean: Technological and nutritional potential. *Crit. Rev. Food Sci. Nutr*., **55(5),** 670-688. https://doi.org/10.1080/ 10408398.2012.671202

Dhaliwal, S.S., Toor A.S., Gaber A., Sharma S., Randhawa M.K., Pandher L.K., Hossain A., Singh P., Sharma V., Verma V., Walia S.S., Alhomrani M. and Shukla A.K. (2021). Long-term integrated nutrient management in the maize-wheat cropping system in alluvial soils of north-western India: Influence on soil organic carbon, microbial activity and nutrient status. *Agronomy*, **11(11),** 2258. https://doi.org/10.3390/agronomy11112258

Didinger, C. and Thompson H.J. (2021). Defining nutritional and functional niches of legumes: A call for clarity to distinguish a future role for pulses in the Dietary Guidelines for Americans. *Nutrients*, **13(4),** 1100. https://doi.org/10.3390/nu13041100

Dineshkumar, R., Sampathkumar P., Sharmiladevi N., Lakshmi L.P., Duraimurugan M., Rasheeq A.A. and Arumugam A. (2020). Microalgal liquid biofertilizer and biostimulant effect on green gram (Vigna radiata L.) in an experimental cultivation. Biomass Convers. *Biorefin*., **12(8),** 3007-3027. https://doi.org/10.1007/s13399-020-00857-0

Duncan, D.B. (1955). Multiple range and multiple F tests. Biometrics, 11(1), 1-42. https://doi.org/10.2307/3001478

Favero, V.O., Carvalho R.H., Urquiaga S., Xavier G.R., Leite A.B.C., Coelho M.R.R., Rumjanek N.G. and Motta V.M. (2021). *Bradyrhizobium* as the only rhizobial inhabitant of mung bean (*Vigna radiata*) nodules in tropical soils: A strategy based on microbiome for improving biological nitrogen fixation using bio-products. *Front. Plant Sci.*, **11,** 602645. https://doi.org/10.3389/fpls.2020.602645

Gao, C., El-Sawah A.M., Sheteiwy M.S., Shaghaleh H., Alhaj Hamoud Y. and Ali D.F.I. (2020). The integration of bio and organic fertilizers improves plant growth, grain yield, quality and metabolism of hybrid maize (*Zea mays* L.). *Agronomy*, **10(3),** 319. https://doi.org/10.3390/agronomy10030319

Gautam, A., Guzman J., Kovacs P. and Kumar S. (2021). Manure and inorganic fertilization impacts on soil nutrients, aggregate stability, and organic carbon and nitrogen in different aggregate fractions. *Arch. Agron. Soil Sci*., **68(9),** 1261-1273. https://doi.org/10.1080/03650340.2021.1887480

Goldan, E., Panainte-Lehadus M., Irimia O., Barsan N., Tomozei C., Culea M., Mosnegutu E., Nedeff V. and Chitimus D. (2023). Assessment of manure compost used as soil amendment: A review. *Processes*, **11(4),** 1167. https://doi.org/10.3390/pr11041167

Grdeń, P. and Jakubczyk A. (2023). Health benefits of legume seeds. *J. Sci. Food Agric.*, **103(11),** 5213-5220. https://doi.org/10.1002/jsfa.12585

Gupta, G., Dhar S., Kumar A., Choudhary A.K., Dass A., Sharma V.K., Shukla L., Upadhyay P.K., Das A., Jinger D., Rajpoot S.K., Sannagoudar M.S., Kumar A., Bhupenchandra I., Tyagi V., Joshi E., Kumar K., Dwivedi P. and Rajawat M.V.S. (2022). Microbes-mediated integrated nutrient management for improved rhizo-modulation, pigeonpea productivity, and soil bio-fertility in a semi-arid agro-ecology. *Front. Microbiol*., **13,** 924407. https://doi.org/10.3389/fmicb.2022.924407

Holatko, J., Latal O., Mustafa A., Hammerschmiedt T., Jaskulska I., Radziemska M., Baltazar T., Kintl A., Brtnicky M. and Malicek O. (2022). Carbon-enriched organic amendments differently affect the soil chemical, biological properties and plant biomass in a cultivation time-dependent manner. *Chem. Biol. Technol. Agric*., **9(1),** 58. https://doi.org/10.1186/s40538-022-00319-x

Hoque, T.S., Mia S., Dey D.K., Nahar N., Solaiman Z.M., Hasan A.K., Kader M.A. and Hasan M.A. (2022). Nutrient release from vermicompost under anaerobic conditions in two contrasting soils of Bangladesh and its effect on wetland rice crop. *Agriculture*, **12(3),** 376. https://doi.org/10.3390/agriculture12030376

Hou, D., Yousaf L., Xue Y., Hu J., Wu J., Hu X., Feng N. and Shen Q. (2019). Mung bean (*Vigna radiata* L.): Bioactive polyphenols, polysaccharides, peptides, and health benefits. *Nutrients*, **11(6),** 1238. https://doi.org/10.3390/nu 11061238

Huang, D. and Imran I. (2023). Nano-black carbon improves phosphorus uptake and sustains soil and plant health under biodynamic agriculture. *Commun. Soil Sci. Plant Anal*., **55(4),** 457-472. https://doi.org/10.1080/00103624.2023.2269244

Imran, I. (2024). Integration of organic, inorganic and biofertilizer improves maize-wheat system productivity and soil nutrients. *J. Plant Nutr*., **47(15),** 2494-2510. https://doi.org/10.1080/01904167.2024.2354190

Iqbal, A., Khan A., Jiang L., Akhtar K., Wei S., Ullah S., He L., Zhao Q., Munsif F. and Ali I. (2019). Organic manure coupled with inorganic fertilizer: An approach for the sustainable production of rice by improving soil properties and nitrogen use efficiency. *Agronomy*, **9(10),** 651. https://doi.org/10.3390/agronomy9100651

Jackson, M.L. (1973). *Soil Chemical Analysis.* Prentice-Hall of India Pvt. Ltd., New Delhi, India.

Joshi, R., Singh J. and Vig A.P. (2014). Vermicompost as an effective organic fertilizer and biocontrol agent: Effect on growth, yield and quality of plants. *Rev. Environ. Sci. Biotechnol*., **14(1),** 137-159. https://doi.org/10.1007/s11157-014-9347-1

Jouquet, E., Bloquel E., Doan T.T., Ricoy M., Orange D., Rumpel C. and Duc T.T. (2011). Do compost and vermicompost improve macronutrient retention and plant growth in degraded tropical soils? *Compost Sci. Util*., **19(1),** 15-24. https://doi.org/10.1080/1065657X.2011.10736972

Khan, M.T., Aleinikovienė J. and Butkevičienė L.-M. (2024). Innovative organic fertilizers and cover crops: Perspectives for sustainable agriculture in the era of climate change and organic agriculture. *Agronomy*, **14(12),** 2871. https://doi.org/10.3390/agronomy14122871

Langyan, S., Kumar A., Yadava P., Bhardwaj R., Bhardwaj V., Tripathi K., Khan F.N., Gautam R.K. and Bhardwaj R. (2022). Nutritional and food composition survey of major pulses toward healthy, sustainable, and biofortified diets. *Front. Sustain. Food Syst.*, **6,** 878269. https://doi.org/10.3389/fsufs.2022.878269

Li, H.-P., Kaplan D.I., Otosaka S., Jones W.L., Brinkmeyer R., Yeager C.M., Schwehr K.A., Santschi P.H., Xu C., Ho Y.-F., Roberts K.A. and Zhang S. (2012). Bacterial production of organic acids enhances H_2O_2-dependent iodide oxidation. *Environ. Sci. Technol.*, **46(9),** 4837-4844. https://doi.org/10.1021/es203683v

Lindsay, W.L. and Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Sci. Soc. Am. J.*, **42(3),** 421–428. https://doi.org/10.2136/sssaj1978.03615995004200030009x

Lupatini, M., Kuramae E.E., De Hollander M., Korthals G.W. and Janssens T.K.S. (2016). Soil microbiome is more heterogeneous in organic than in conventional farming system. *Front. Microbiol*., **7,** 2064. https://doi.org/10.3389/fmicb.2016.02064

Tahat, M.M., Alananbeh K.M., Leskovar D.I. and Othman Y.A. (2020). Soil health and sustainable agriculture. *Sustainability*, **12(12),** 4859.

Mehta, A., Yadav A., Kumari K. and Kumar A. (2024). Waste utilization in horticulture: An overview. *J. Exp. Agric. Int*., **46(5),** 742-749. https://doi.org/10.9734/jeai/2024/v46i52427

Mondal, S., Mallikarjun M., Ghosh M., Ghosh D.C. and Timsina J. (2016). Influence of integrated nutrient management (INM) on nutrient use efficiency, soil fertility and productivity of hybrid rice. *Arch. Agron. Soil Sci*., **62(11),** 1521-1529. https://doi.org/10.1080/03650340.2016.1148808

Mwende Muindi, E. (2019). Understanding soil phosphorus. *Int. J. Plant Soil Sci.*, **31(2),** 1-18. https://doi.org/10.9734/ijpss/2019/v31i230208

Nair, R.M., Keatinge J. (Dyno), Hughes J.D., Thavarajah D., Easdown W.J., Yang R. and Thavarajah P. (2013). Biofortification of mungbean (*Vigna radiata*) as a whole food to enhance human health. *J. Sci. Food Agric*., **93(8),** 1805-1813. https://doi.org/10.1002/jsfa.6110

Nath, M. and Tuteja N. (2015). NPKS uptake, sensing, and signaling and miRNAs in plant nutrient stress. *Protoplasma*, **253(3),** 767-786. https://doi.org/10.1007/s00709-015-0845-y

Nurdiawati, A., Purwoko B.A., Akbar M.A., Prawisudha P., Maxiselly Y., Suherman C. and Yoshikawa K. (2019). Liquid feather protein hydrolysate as a potential fertilizer to increase growth and yield of patchouli (*Pogostemon cablin* Benth.) and mung bean (*Vigna radiata*). *Int. J. Recycl. Org. Waste Agric*., **8(3),** 221-232. https://doi.org/10.1007/s40093-019-0245-y

Oyege, I. and Balaji Bhaskar M.S. (2023). Effects of vermicompost on soil and plant health and promoting sustainable agriculture. Soil Syst., 7(4), 101. https://doi.org/10.3390/soilsystems7040101

Panse, V.G. and Sukhatme P.V. (1967). Statistical methods for agricultural workers. Indian Council of Agricultural Research, New Delhi, pp. 152-161.

Parca, F., Unay A. and Koca Y.O. (2018). Nutritional and antinutritional factors of some pulses seed and their effects on human health. *Int. J. Second. Metab*., **5(4),** 331-342. https://doi.org/10.21448/ijsm.488651

Park, S.H., Kang B.R., Kim J., Lee Y., Nam H.S. and Lee T.K. (2024). Enhanced soil fertility and carbon dynamics in organic farming systems: The role of arbuscular mycorrhizal fungal abundance. *J. Fungi*, **10(9)**, 598. https://doi.org/10.3390/jof10090598

Pathma, J. and Sakthivel N. (2012). Microbial diversity of vermicompost bacteria that exhibit useful agricultural traits and waste management potential. *SpringerPlus*, **1(1)**. https://doi.org/10.1186/2193-1801-1-26

Patra, A., Sharma V.K., Purakayastha T.J., Barman M., Kumar S., Chobhe K.A., Chakraborty D., Nath D.J. and Anil A.S. (2020). Effect of long-term integrated nutrient management (INM) practices on soil nutrients availability and enzymatic activity under acidic Inceptisol of north-eastern region of India. *Commun. Soil Sci. Plant Anal*., **51(9),** 1137-1149. https://doi.org/10.1080/00103624.2020.1751185

Pittarello, M., Morari F., Dal Ferro N., Chiarini F. and Carletti P. (2021). Influence of tillage and crop rotations in organic and conventional farming systems on soil organic matter, bulk density and enzymatic activities in a short-term field experiment. *Agronomy*, **11(4),** 724. https://doi.org/10.3390/agronomy11040724

Rehman, S.U., Aprile A., Fanizzi F.P., De Castro F. and Benedetti M. (2023). Vermicompost: Enhancing plant growth and combating abiotic and biotic stress. *Agronomy*, **13(4),** 1134. https://doi.org/10.3390/agronomy13041134

Rengel, Z. (2015). Availability of Mn, Zn and Fe in the rhizosphere. *J. Soil Sci. Plant Nutr.*, **15(2),** 397-409. https://doi.org/10.4067/S0718-95162015005000036

Rey, C.S., Shetty K.G., Jayachandran K., Balaji Bhaskar M.S. and Oyege I. (2024). Evaluation of vermicompost, seaweed, and algal fertilizers on soil fertility and plant production of sun hemp. *Soil Syst*., **8(4),** 132. https://doi.org/10.3390/soilsystems8040132

Rupani, P.F., Ghole V., Abbaspour M., Lee C.T., Embrandiri A. and Ibrahim M.H. (2018). Effects of different vermicompost extracts of palm oil mill effluent and palm-pressed fiber mixture on seed germination of mung bean and its relative toxicity. *Environ. Sci. Pollut. Res*., **25(36),** 35805-35810. https://doi.org/10.1007/s11356-018-1875-8

Sandhu, K. and Singh A. (2020). Strategies for the utilization of the USDA mung bean germplasm collection for breeding outcomes. *Crop Sci*., **61(1),** 422-442. https://doi.org/10.1002/csc2.20322

Sarma, R.K. and Saikia R. (2013). Alleviation of drought stress in mung bean by strain Pseudomonas aeruginosa GGRJ21. *Plant Soil*, **377(1-2),** 111-126. https://doi.org/10.1007/s11104-013-1981-9

Schröder, C., Larsen O.C., Häfner F. and Krause A. (2021). Urban organic waste for urban farming: Growing lettuce using vermicompost and thermophilic compost. *Agronomy*, **11(6),** 1175. https://doi.org/10.3390/agronomy11061175

Singh, Y.P., Arora S., Mishra V.K., Dixit H. and Gupta R.K. (2019). Plant and soil responses to the combined application of organic amendments and inorganic fertilizers in degraded sodic soils of Indo-Gangetic Plains. *Commun. Soil Sci. Plant Anal*., **50(20),** 2640-2654. https://doi.org/10.1080/00103624.2019.1671446

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soil. *Curr. Sci.*, **25(8),** 259–260.

Suyal, D.C., Singh D.K., Soni R. and Goel R. (2021). Microbiome change of agricultural soil under organic farming practices. *Biologia*, **76(4),** 1315-1325. https://doi.org/10.2478/s11756-021-00680-6

Toor, M.D., Ullah I., Ghfar A.A., Ay A., Demirkaya S., Jamal A., Ronga D., Kızılkaya R., Zia A., Di Serio A. and Mihoub A. (2024). Vermicompost rate effects on soil fertility and morpho-physio-biochemical traits of lettuce. *Horticulturae*, **10(4),** 418. https://doi.org/10.3390/horticulturae10040418

United States Department of Agriculture (USDA). (1951). *Soil Survey Manual* (USDA Handbook No. 18). U.S. Government Printing Office, Washington, DC

Wang, X., Wang C., Sui J., Liu Z., Li Q., Ji C., Song X., Hu Y., Wang C., Sa R., Zhang J., Du J. and Liu X. (2018). Isolation and characterization of phosphofungi, and screening of their plant growth-promoting activities. *AMB Express*, **8(1).** https://doi.org/10.1186/s13568-018-0593-4

Wu, B., Zhang M., Zhai Z., Dai H., Yang M., Zhang Y. and Liang T. (2024). Soil organic carbon, carbon fractions, and microbial community under various organic amendments. *Sci. Rep*., **14(1).** https://doi.org/10.1038/s41598-024-75771-w

Xu, J., Wolters-Arts M., Rieu I., Huber H. and Mariani C. (2017). Heat stress affects vegetative and reproductive performance and trait correlations in tomato (*Solanum lycopersicum*). *Euphytica*, 213(7). https://doi.org/10.1007/s10681-017-1949-6

Yadav, A. and Yadav K. (2024). Regulation of plant-microbe interactions in the rhizosphere for plant growth and metabolism: Role of soil phosphorus. *IntechOpen*. https://doi.org/10.5772/intechopen.112572

Yatoo, A.M., Bhat S.A., Zaheen Z., Baba Z.A. and Ali M.N. (2022). Production of nutrient-enriched vermicompost from aquatic macrophytes supplemented with kitchen waste: Assessment of nutrient changes, phytotoxicity, and earthworm biodynamics. *Agronomy*, **12(6),** 1303. https://doi.org/10.3390/agronomy12061303