RESEARCH ARTICLE Indian Journal of Agricultural Research, Volume 60 Issue 4: 501-506 (April 2026)

Organic Amendments Improve Soil Moisture Retention and Soil Properties under French Bean (*Phaseolus vulgaris* L.) Cultivation

Sagar Balmiki[1], Manoj Dutta[1], Hapemo Ngullie K.[1], Sewak Ram[1]
Sorenthung Patton[1], Jurisandhya Barik Bordoloi[2], D Nongmaithem[3]

10.18805/IJARe.A-6473

ABSTRACT

Background: Predominantly cultivated in the areas where cool weather prevails, French bean (*Phaseolus vulgaris* L.) is a nutritionally imperative legume crop grown for its protein rich seeds and green pods. The hilly region of Nagaland is well suited for this crop where it is grown as a *kharif* as well as a *rabi* crop. Due to steep slopes and prevailing soil degradation in the region, this study aims to deliver critical analysis on how the incorporation of organic manures may help restore the soil health and productivity so that sustainable agriculture can be achieved.

Methods: An experiment was conducted to investigate how soil moisture and soil properties are influenced by organic amendments under French bean (*Phaseolus vulgaris* L.) cultivation during the *rabi* season of 2024 at the research farm of ICAR KVK Peren, Nagaland. Randomized block design (RBD) was adopted for the aforesaid experiment with 3 replications and 8 treatments specifically, control (T_1), FYM @ 10 t ha^{-1} (T_2), poultry litter @ 5 t ha^{-1} (T_3), forest litter @ 5 t ha^{-1} (T_4), pig manure @ 5 t ha^{-1} (T_5), goat manure @ 5 t ha^{-1} (T_6), vermicompost @ 5 t ha^{-1} (T_7) and enriched compost @ 2.5 t ha^{-1} (T_8).

Result: Outcomes of the study revealed that vermicompost (T_7) delivered the peak soil moisture at early stages (21.71% and 22.22%) at 15 and 30 DAS, respectively, while forest litter (T_4) maintained higher soil moisture at later stages (23.03%-25.06%) at 45 and 60 DAS and 24.11% at 75 DAS. Poultry litter (T_3) significantly improved soil chemical and biological properties, recording highest soil pH (5.73), organic carbon (2.01%), available nitrogen (532.82 kg ha^{-1}), available potassium (331.60 kg ha^{-1}), soil microbial biomass carbon (220.02 µg g^{-1}), dehydrogenase activity (4.74 µg TPF g^{-1} soil h^{-1}) and acid phosphatase activity (63.53 µg PNP g^{-1} soil h^{-1}).

Key words: French bean, Organic manures, Productivity, Soil fertility, Soil moisture conservation.

INTRODUCTION

Organic manures serve a crucial role in providing essential nutrients to the soil with cost effective and minimal environmental impact. Small and marginal farmers with nominal land holdings largely depends on organic manures as it supplies essential macro and micro nutrients which are indispensable for crop growth and productivity. It reduces the dependency of inorganic fertilizers consequently leaning towards sustainable crop production (Gelaye, 2023). In Nagaland with special reference to Tuensang district, French beans production provides 46.96% of the total income of farmers (Patra and Benjongtoshi, 2023). The hilly region of North-East India and particularly Nagaland, erratic rainfall pattern coupled with hilly slopes damage the stability of the soil and retention of soil moisture making it strenuous to sustain, ultimately being lost through runoff and erosion (Bhattacharjee, 2019). Collection of water through traditional methods like Rüza or Zabo especially in Nagaland helps reduce runoff and conserve more water (Das, 2025). Adoption of integrated nutrient management which focuses on utilization of organic manures, crop residues and some essential fertilizers boost the soils ability to stabilize the soil structure, moisture conservation and infiltration of runoff water (Haokip *et al.,* 2023). Due to undulating terrain and steep slopes in Nagaland, proper soil and water conservation measures are the utmost priority to help reduce erosion and conservation of soil moisture (Ngullie *et al*., 2025). The addition of organic manures plays an important role in enhancing the physical, chemical and biological characteristics

[1]Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University, Medziphema Campus-797 106, Nagaland, India.
[2]Department of Soil Science, School of Agricultural Sciences, Nagaland University, Medziphema Campus-797 106, Nagaland, India.
[3]Department of Agronomy, School of Agricultural Sciences, Nagaland University, Medziphema Campus-797 106, Nagaland, India.

Corresponding Author: Manoj Dutta, Department of Soil and Water Conservation, School of Agricultural Sciences, Nagaland University, Medziphema Campus-797 106, Nagaland, India.
Email: manojdutta@nagalanduniversity.ac.in
ORCID: 0009-0001-4967-7130

How to cite this article: Balmiki, S., Dutta, M., Ngullie, K.H., Ram, S., Patton, S., Bordoloi, J.B. and Nongmaithem, D. (2026). Organic Amendments Improve Soil Moisture Retention and Soil Properties under French Bean (*Phaseolus vulgaris* L.) Cultivation. *Indian Journal of Agricultural Research.* **60(4):** 501-506. doi: 10.18805/IJARe.A-6473.

Submitted: 21-10-2025 **Accepted:** 16-02-2026 **Online:** 28-02-2026

of the soil. It conserves and maintains the soil health providing adequate nutrient supply and most importantly improving the ecological balance of the natural soil conditions (Verma *et al.,* 2024). Changkiri *et al.* (2024) stated that incorporation of organic manures along with inorganic fertilizers tends to elevate soil moisture retention, improves soil fertility and thus increases the yield and yield attributes of the soil which ultimately sustains the profitability in French bean growers. With reference to a five-year study conducted in Meghalaya by Saha and Mishra, (2009) it has been noticed that incorporation of organic residues like FYM, ambrosia weed and jungle grasses as mulch rejuvenates the soil fertility, soil structure, moisture conservation and runoff infiltration which ultimately increases crop productivity in the hilly topography of Northeast India. The incorporation of FYM @ 5 t ha^{-1} performed considerably better than all other treatments under pea cultivation in the hilly Northeastern Region of India, Nagaland (Haiguipeung *et al.,* 2025). This study focuses with the enhancement of soil health and sustainable crop production, which have become a major concern in modern agriculture practices. To meet the global food demand, excessive use of chemical fertilizers amplified significantly, so as to tackle this concern and to justify that organic manures can likewise augment productivity whereby contributing to a cleaner environment, the present study was precisely steered. The nutrient deficient soil in the degraded slopes of NER Region of India may be enhanced and rejuvenated with the integration of organic manures as it improves the soil structure, increases water holding capacity, supply essential macro and micronutrients, enhances the microbial activity, improves soil organic carbon, improves the availability of nutrients to the plant, reduces the dependency of chemical fertilizers and ultimately promotes sustainable farming systems. This study provides a methodical detail on how the integration of organic manures influences the soil physical and chemical parameters as well as moisture dynamics of the experimental site and the concerned areas.

MATERIALS AND METHODS

The experiment was conducted at the research field of ICAR KVK Peren during the *rabi* season of the year 2024, which is located at 25°39′48″ North latitude and 93°38′21″ East longitude having an altitude of 295.8 m above mean sea level. Soil samples were collected at 15 cm depth with an auger to evaluate various soil properties (Table 1). The experiment was carried out following randomized block design (RBD) with 3 replications to control field variability across plots. The French bean variety used in the experiment was *Arka suvidha* (Bushy type). The number of treatments used in the experiment was eight *i.e.* control (T_1), FYM @ 10 t ha^{-1} (T_2), Poultry litter@ 5 t ha^{-1} (T_3), Forest litter @ 5 t ha^{-1} (T_4), Pig manure @ 5 t ha^{-1} (T_5), Goat manure @ 5 t ha^{-1} (T_6), Vermicompost @ 5 t ha^{-1} (T_7), Enriched compost @ 2.5 t ha^{-1} (T_8). Soil moisture was recorded at 15 days' interval to assess the moisture status. To appraise the consequences of organic manures on soil properties, the present study analyzed a range of physical and chemical parameters, including soil moisture content, bulk density, particle density, porosity, water-holding capacity, mean weight diameter, percentage of aggregates, dispersion ratio, erosion index, soil pH, organic carbon, cation exchange capacity (CEC) and available nitrogen (N), phosphorus (P), potassium (K) and sulfur (S). Gomez and Gomez (2004) technique was followed in the analysis of data.

RESULTS AND DISCUSSION

Soil moisture conservation

Farm yard manure and vermicompost optimistically influenced soil moisture regime of the cultivated plot resulting in elevated mustard grain and stover yield (Bhanwaria *et al*., 2022). Following the findings of the research, the soil moisture conservation status recorded at 15 days' interval revealed significant variations among treatments with organic manures showing notable progress over control as outlined in Table 2. Vermicompost @ 5 t ha^{-1} escalated the moisture content in 15 DAS (21.71%) and 30 DAS (22.22%), meanwhile elevated moisture level was also observed under forest litter from 45 DAS (23.03%), 60 DAS (25.06%) and 75 DAS (24.11%). Lower moisture content (19.26%) was noted in the plots where enriched compost was applied in 15 DAS. Plots where no amendments were added (control) also resulted in lower moisture content *i.e.* 18.61%, 17.22% and 17.52% at 30, 60 and 75 DAS, respectively. Vermicompost and FYM improved moisture by adding more organic matter and making the soil more

Table 1: Initial soil properties and methods employed for determination.

Soil parameters	Value	Methods employed	Reference
pH	5.25	Glass electrode pH meter (1: 2.5 soil and water ratio)	Jackson, 1973
Organic cabon (%)	0.95	Walkley and Black, rapid titration	Jackson, 1973
Cation exchange capacity {cmol (p+) kg^{-1}}	6.49	Centrifuge method	Baruah and Barthakur, 1997
Available N (kg ha^{-1})	430.57	Alkaline potassium permanganate method	Subbiah and Asija, 1956
Available P (kg ha^{-1})	16.69	Bray's No.1 method	Bray and Kurtz, 1945
Available K (kg ha^{-1})	156.80	Ammonium acetate method	Hanway and Heidel, 1952

porous, which helped it hold onto water. These trends support the idea that organic inputs can help the soil's physical condition in rainfed hills. Observations of several authors like Singh *et al.* (2011) and Mishra *et al.* (2020) presented parallel outcomes where application of organic manures enhanced the soil properties and lowered the moisture losses through evaporation.

Soil physical properties

Studies initiated in the Hetao Irrigation District, China which was carried out for a nine-year period highlighted improved soil physical properties of the experimented areas which was acknowledged by higher yield received following the cultivation of wheat and sunflower (Zhao *et al*., 2024). In this study, a significant regression of soil bulk density was perceived with the induction of organic manures into the soil. Recorded observation revealed 1.28 g cm^{-3} incorporating forest litter (T_4), vermicompost (T_7) and enriched compost (T_8) which was noted at 5.88% reduction from control (T_1) 1.36 g cm^{-3}. The addition of organic manures compiles the organic matter in the soil resulting in the reduction of soil compaction and improves the soil structure (Mahmood *et al.,* 2017). The data related to soil physical properties is systematically presented in Table 3. The particle density of the soil ranged from (2.15-2.50 g cm^{-3}). The porosity of the soil was recorded to be highest under forest litter (T_4) 48.80% which was followed by poultry litter (T_3) 46.17% and enriched compost (T_8) 46% which presents a sign of improved soil aggregation and formation of root bio pore. This highlights the findings recorded by Khoirunnisak *et al.* (2025). The water holding capacity of the soil was higher with the indulgence of forest litter and vermicompost. The results of this align with the outcomes of Koutika, (2025). Poultry litter managed to output the most elevated mean weight diameter (2.23 mm) which was followed by FYM (1.97 mm) and enriched compost (1.97 mm) whereas the least was recorded in vermicompost treated plots (1.85 mm). The influence of organic manures, especially with the incorporation of poultry litter significantly improves the soil aggregation and microbial activities which directly help the soil to increase the soil organic carbon content. These outcomes are parallel with the findings of Raju and Larkin, (2025). Soil aggregates improved significantly with the incorporation of poultry litter (75.53%), FYM (65.01%) and enriched compost (64.48%). The role of added poultry litter enhanced soil aggregation as elevated soil microbial biomass carbon and organic matter increased the binding ability of the soil; these findings are in line of outcomes

Table 2: Effect of organic manures on soil moisture conservation.

Treatments	Soil moisture content (%)				
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS
T_1 - Control	19.41	18.61	20.75	17.22	17.52
T_2 - FYM @ 10 t ha^{-1}	19.86	20.41	22.05	25.05	21.07
T_3 - Poultry litter @ 5 t ha^{-1}	20.04	21.29	19.38	18.76	20.12
T_4 - Forest litter @ 5 t ha^{-1}	20.40	21.38	23.03	25.06	24.11
T_5 - Pig manure @ 5 t ha^{-1}	19.77	21.15	19.10	22.04	20.07
T_6 - Goat manure @ 5 t ha^{-1}	18.26	20.30	20.06	18.11	19.41
T_7 - Vermicompost @ 5 t ha^{-1}	21.71	22.22	20.30	23.08	22.11
T_8 - Enriched compost @ 2.5 t ha^{-1}	19.26	19.60	20.15	23.10	20.12
SEm (±)	0.07	0.08	0.07	0.09	0.09
CD at 5%	0.22	0.24	0.20	0.27	0.27

Table 3: Effect of organic manures on soil physical properties.

Treatments	Soil physical properties							
	Bulk density (g cm^{-3})	Particle density (g cm^{-3})	Porosity (%)	Water holding capacity (%)	Mean weight diameter (mm)	Per cent aggregates (%)	Dispersion ratio	Erosion index
T_1 - Control	1.36	2.5	45.47	40.05	1.94	62.10	32.73	12.14
T_2 - FYM @ 10 t ha^{-1}	1.29	2.22	41.93	41.06	1.97	65.01	26.47	8.80
T_3 - Poultry litter @ 5 t ha^{-1}	1.29	2.41	46.17	40.77	2.23	73.53	25.99	8.50
T_4 - Forest litter @ 5 t ha^{-1}	1.28	2.50	48.80	41.59	1.92	63.36	28.31	9.40
T_5 - Pig manure @ 5 t ha^{-1}	1.33	2.15	38.03	41.06	1.94	63.52	29.81	9.91
T_6 - Goat manure @ 5 t ha^{-1}	1.30	2.15	39.10	40.91	1.94	64.25	30.75	10.33
T_7 - Vermicompost @ 5 t ha^{-1}	1.28	2.17	40.43	41.24	1.85	63.93	27.57	9.16
T_8 - Enriched compost @ 2.5 t ha^{-1}	1.28	2.43	46.00	39.10	1.97	64.48	29.52	9.84
SEm (±)	0.02	0.11	0.85	0.53	0.04	1.18	0.48	0.24
CD at 5%	0.05	NS	2.59	1.59	0.13	3.58	1.45	0.72

Table 4: Effect of organic manures on soil chemical properties.

Treatments	Soil chemical properties						
	pH	Organic carbon (%)	Cation exchange capacity {cmol (p+) kg^{-1}}	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available S (ppm)
T_1- Control	5.07	1.10	6.6	422.29	20.17	147.27	3.78
T_2 - FYM @ 10 t ha^{-1}	5.30	1.66	5.35	522.72	21.87	208.60	9.51
T_3 - Poultry litter @ 5 t ha^{-1}	5.73	2.01	6.06	532.82	22.20	331.60	7.17
T_4 - Forest litter @ 5 t ha^{-1}	5.13	1.64	6.09	529.10	22.19	136.73	7.22
T_5 - Pig manure @ 5 t ha^{-1}	5.43	1.66	6.76	527.59	22.00	163.07	9.27
T_6 - Goat manure @ 5 t ha^{-1}	5.17	1.68	7.14	510.99	21.89	212.53	7.82
T_7 - Vermicompost @ 5 t ha^{-1}	5.53	1.73	6.86	513.68	21.61	172.60	9.60
T_8 - Enriched compost @ 2.5 t ha^{-1}	5.27	1.71	7.22	529.93	22.82	204.53	9.89
SEm (±)	0.19	0.07	0.28	14.12	0.37	10.04	0.11
CD at 5%	0.58	0.22	0.84	42.83	1.13	30.45	0.35

described by Li *et al*. (2023). Lower dispersion ratio was recorded with the addition of poultry manures (25.99) while FYM and vermicompost yielded (26.47) and (27.57) respectively. These outcomes were supported by the results obtained by Singh *et al.* (2007). Erosion index significantly reduced with the addition of poultry manure (8.50), FYM (8.80) and vermicompost (9.16). Control (T_1) maintained the highest erosion index (12.14). The incorporation of organic amendments like poultry litter and FYM improves the structure of the soil which helps in better infiltration and root penetration ability of the crops. The soil losses may be controlled by amending these manures into the soil (Bhattacharya *et al.,* 2023 and Rangasami *et al.* (2024).

Soil chemical properties

Augmented pH of the soil were observed with the integration of poultry litter (T_3) (5.73) followed by vermicompost (5.53). Yuvaraj *et al.* (2018) and Bolan *et al.* (2010) stated that the addition of organic amendments like poultry litter and vermicompost increased the soil pH neutralizing acidity and enhancing microbial decomposition of organic acids. The data of soil chemical properties is highlighted in Table 4. Poultry litter (T_3) increased the organic carbon of the soil significantly (2.01%) in comparison to control (T_1) noting (1.10%) showing 82% increase. Vermicompost (1.73%) and enriched compost (1.71%) also increased the soil organic carbon in comparison to control. This outcome may be because of formation of humus and higher inputs of labile C. Addition of enriched compost (T_8) and goat manure (T_6) registered higher CEC *i.e*. 7.22 and 7.14 cmol (p+) kg^{-1} which might be due to more negatively charged functional group in stabilized organic matter. These findings are in line with those of Chen *et al.* (2020). The highest available nitrogen (532.82 kg ha^{-1}) was recorded under poultry litter which was 26.17% higher than control (422.29 kg ha^{-1}), closely followed by enriched compost (529.93 kg ha^{-1}) and forest litter (529.10 kg ha^{-1}). The rise in available N with poultry litter may be due to rapid mineralization of nitrogen. These results align with the findings of DeLaune *et al.* (2004). Available P peaked with enriched compost (22.82 kg ha^{-1}) which was slightly ahead of poultry litter (22.20 kg ha^{-1}) and forest litter (22.19 kg ha^{-1}). Similar trends were observed by Erhunmwunse *et al.* (2019). Available K (331.60 kg ha^{-1}) was observed highest in poultry litter, followed by goat manure (212.53 kg ha^{-1}) and FYM (208.60 kg ha^{-1}) whereas forest litter procured the lowest available K (136.73 kg ha^{-1}). These results are in line with the findings of Toluwase *et al.* (2020) and Reiter and Middleton (2016) where they stated that poultry litter incorporation considerably improved the available potassium status of the soil. Available S was observed highest in enriched compost (9.89 ppm), followed by vermicompost (9.60 ppm) and FYM (9.51 ppm) and least was reported where no amendments were added (3.78 ppm). The increase in available sulphur with enriched compost and vermicompost treatments is due to the sulphur-rich organic materials and enhanced microbial decomposition. This assumption was also supported by Solanki *et al*. (2020) where in their study they resolved that organic manures like vermicompost and FYM significantly augments the overall soil health and productivity of cultivated garlic.

CONCLUSION

Based on the outcomes of the research it is clear that organic manures significantly improved soil moisture status. The treatment vermicompost performed better at early stages of crop growth, while forest litter maintained higher moisture at later stages. Poultry litter @ 5 t ha^{-1} noticeably enhanced soil chemical properties like pH, organic carbon, available N and K. Available P (22.82 kg ha^{-1}) peaked with enriched compost followed by the addition of poultry litter (22.20 kg ha^{-1}). Bulk density declined significantly with forest litter, vermicompost and enriched compost showing a reduction of 5.88% in contrast to control. The water holding capacity of the soil was highest with the incorporation of forest litter and vermicompost. The biological properties of soil were enhanced by poultry litter treatment. Soil microbial biomass carbon (220.02 µg g^{-1}), dehydrogenase activity (4.74 µg TPF g^{-1} soil h^{-1}) and acid

phosphatase activity (63.53 µg (PNP) g^{-1} soil h^{-1}) were significantly improved by the poultry litter treatment. Under moisture conservation forest litter and vermicompost performed better than all other treatments.

ACKNOWLEDGEMENT

The present study was supported by the Department of Soil and Water Conservation, Nagaland University, School of Agricultural Sciences, Medziphema Campus.

Disclaimers

The views and conclusions expressed in this article are solely those of the authors and do not necessarily represent the views of their affiliated institutions. The authors are responsible for the accuracy and completeness of the information provided, but do not accept any liability for any direct or indirect losses resulting from the use of this content.

Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this article. No funding or sponsorship influenced the design of the study, data collection, analysis, decision to publish, or preparation of the manuscript.

REFERENCES

Baruah, T.C. and Barthakur, H.P. (1997). A Text Book of Soil Analysis. Vikas Publishing House Pvt. Ltd., New Delhi.

Bhanwaria, R., Singh, B. and Musarella, C.M. (2022). Effect of organic manure and moisture regimes on soil physiochemical properties, microbial biomass Cmic:Nmic:Pmic turnover and yield of mustard grains in arid climate. *Plants*. **11(6):** 722. https://doi.org/10.3390/plants11060722.

Bhattacharjee, S.P. (2019). Ground water conservation and management in North Eastern India adopting traditional wisdom. *Journal of the Geological Society of India*. **93(2):** 250-251.

Bhattacharyya, R., Bhatia, A., Ghosh, B.N., Santra, P., Mandal, D., Kumar, G. and Chaudhari, S.K. (2023). Soil degradation and mitigation in agricultural lands in the Indian Anthropocene. *European Journal of Soil Science*. **74(4):** e13388.

Bolan, N.S., Khan, M.A., Saggar, S., Barrell, A.J. and Kim, K.H. (2010). Effect of poultry litter application on agricultural production: A meta-analysis of crop yield, nutrient uptake and soil fertility. *Bioresource Technology*. **101(24):** 9954-9964.

Bray, R.H. and Kurtz, L.T. (1945). Determination of total, organic and available forms of phosphorus in soil. *Soil Science*. **9:** 39-45.

Changkiri, M., Adhikary, N.K., Jha, A. and Kanaujia, S.P. (2024). Integrated nutrient management of French bean (*Phaseolus vulgaris* L.) in subtropical humid zone of Nagaland, India. *Legume Research*. **47(5):** 845-849. doi: 10.18805/LR-5047.

Chen, S., Liu, C. and Wang, J. (2020). Long-term fertilization affects functional soil organic carbon fractions and their relationship with soil fertility in a red soil paddy field. *Science of The Total Environment*. **739:** 140026.

Das, J. (2025). Indigenous knowledge and sustainable development: Rüza-A traditional water management practice in Phek district, Nagaland. *Sustainable Development*. **33(1):** 349-363.

DeLaune, P.B., Moore Jr, P.A., Daniel, T.C. and Lemunyon, J.L. (2004). Effect of chemical and microbial amendments on ammonia volatilization from composting poultry litter. *Journal of Environmental Quality*. **33(2):** 728-734.

Erhunmwunse, A.S., Olayinka, A. and Atoloye, I.A. (2019). Nutrient mineralization from nitrogen- and phosphorus-enriched poultry manure compost in an ultisol. *Communications in Soil Science and Plant Analysis*. **50(2):** 185-197.

Gelaye, Y. (2023). Effect of combined application of organic manure and nitrogen fertilizer rates on yield and yield components of potato: A review. *Cogent Food and Agriculture*. **9(1):** 2217603. doi: 10.1080/23311932.2023.2217603.

Gomez, K.A. and Gomez, A.A. (2004). Statistical procedures for agricultural research. John Wiley and Sons.

Haiguipeung, Hapemo, N.K., Ram, S. and Dutta, M. (2025). Effect of surface soil removal and organic amendments on growth, yield and nutrient content and uptake of pea (*Pisum sativum* L.). *Indian Journal of Agricultural Research*. **59(10):** 1590-1595. doi: 10.18805/IJARe.A-6407.

Hanway, J.J. and Heidel, H. (1952). Soil analysis methods as used in Iowa state college testing laboratory Iowa agriculture. *Science and Education*. **57(1):**187-193.

Haokip, I.C. and Mayanglambam, H.D. (2023). Land degradation in the North Eastern Region of India and its mitigation. *Biological Forum-An International Journal*. **15(12):** 473-479.

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

Khoirunnisak, A., Jannah, H., Rayes, M.L. and Prijono, S. (2025). Organic matter application on subsoil improves soil organic matter, soil aggregate stability and porosity in coffee plantations. *In IOP Conference Series: Earth and Environmental Science*. doi: 10.1088/1755-1315/1466/1/012004.

Koutika, L.S. (2025). Managing tropical forest ecosystems through soil organic carbon storage to boost global warming mitigation, food security, land restoration and conservation of biodiversity (Doctoral Dissertation, Universite de Lorraine).

Li, S., Wang, B., Zhang, X., Wang, H., Yi, Y., Huang, X. and Han, W. (2023). Soil particle aggregation and aggregate stability associated with ion specificity and organic matter content. *Geoderma*. **429:** 116285.

Mahmood, F., Khan, I., Ashraf, U., Shahzad, T., Hussain, S., Shahid, M. and Ullah, S. (2017). Effects of organic and inorganic manures on maize and their residual impact on soil physico-chemical properties. *Journal of Soil Science and Plant Nutrition*. **17(1):** 22-32.

Mishra, P., Sahoo, T.R., Rahman, F.H., Mohapatra, N., Sahoo, P.K., Mohapatra, R.K. and Mishra. S.N. (2020). Effect of different mulching on moisture content in soil, weed dynamics and yield of tomato (*Lycopersicon esculentum* L.) in post flood situation in Coastal Odisha. *Journal of Experimental Agriculture International*. **42(7):** 32-38.

Ngullie, H.K., Dutta, M., Ram, S., Sharma, Y.K., Tzudir, L. and Jamir, A. (2025). Tillage and green manuring effects on nutrient composition, uptake and yield components of maize (*Zea mays* L.). *Environment and Ecology*. **43(3A):** 827-835.

Patra, N.K. and Benjongtoshi. (2023). Sustainable performance of French bean (*Phaseolus vulgaris* L.) cultivation, a livelihood component in Eastern Himalayan Region. *International Journal of Agricultural Sustainability*. **21(1).** doi:10.1080/14735903.2023.2247784.

Raju, S.G. and Larkin, A. (2025). Impact of organic manures on yield and economics of french bean (*Phaseolus vulgaris* L.) under poplar-based agroforestry and open field conditions. *Journal of Advances in Biology and Biotechnology.* **28(5):** 504-510.

Rangasami, S.R.S., Rani, S., Sivakumar, S.D. and Ganesan, K.N. (2024). Forage nutritive quality, yield and quantitative analysis of leguminous fodder cowpea-maize system as influenced by integrated nutrient management in Southern Zone of India. *Legume Research.* **47(4):** 565-573. doi: 10.18805/LR-5277.

Reiter, J. and Middleton, L. (2016). The effects of poultry litter application on potassium availability in agricultural soils. *Journal of Plant Nutrition and Soil Science.* **39(3):** 215-220.

Saha, R. and Mishra, V.K. (2009). Effect of organic residue management on soil hydro-physical characteristics and rice yield in eastern Himalayan region, India. *Journal of Sustainable Agriculture*. **33(2):** 161-176.

Singh, G., Jalota, S.K. and Singh, Y. (2007). Manuring and residue management effects on physical properties of a soil under the rice-wheat system in Punjab, India. *Soil and Tillage Research*. **94(1):** 229-238.

Singh, Y.V., Singh, R.K. and Pabbi, S. (2011). Organic farming in India: Problems and prospects. *Indian Farming.* **61(10):** 10-14.

Solanki, S.S., Chaurasiya, A., Mudgal, A., Mishra, A. and Singh, A.K. (2020). Effect of soil application of sulphur, farm yard manure and vermicompost on soil fertility, growth and yield of garlic (*Allium sativum* L.). *International Journal of Chemical Analysis.* **8(1):** 1370-1373.

Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the estimation of available nitrogen in soils. *Current Science.* **25:** 259-260.

Toluwase Oreoluwa, A., Tolulope Yetunde, A., Joseph, U.E., Chengsen, Z. and Hongyan, W. (2020). Effect of biochar and poultry litter application on chemical properties and nutrient availability of an acidic soil. *Communications in Soil Science and Plant Analysis*. **51(12):** 1670-1679.

Verma, S., Pradhan, S.S., Singh, A. and Kushuwaha, M. (2024). Effect of organic manure on different soil properties: A review. *International Journal of Plant and Soil Science.* **36(5):** 182-187.

Yuvaraj, N., Thangamani, A. and Pounraj, P. (2018). Decomposition of poultry litter through vermicomposting using earthworm *Drawida sulcata* and its effect on plant growth. *International Journal of Zoological Investigations.* **4(2):** 308-312.

Zhao, N., Ma, J., Wu, L., Li, X., Xu, H., Zhang, J., Wang, X., Wang, Y., Bai, L. and Wang, Z. (2024). Effect of organic manure on crop yield, soil properties and economic benefit in Wheat-Maize-Sunflower rotation system, Hetao Irrigation District. *Plants.* **13(16):** 2250. https://doi.org/10.3390/plants13162250.