

Evaluation of Soil Health under Aonla (*Emblica officinalis*) Cultivation with Organic Manure in the Semi-Arid Region of Ayodhya, Uttar Pradesh, India

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ABSTRACT

Soil is a vital natural resource essential for sustaining life on Earth. Preserving and enhancing soil health is critical for ensuring food security, maintaining biodiversity, regulating the climate and promoting human well-being. A field experiment was conducted at the Main Experimental Station (MES) of the Department of Silviculture and Agroforestry, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India, to evaluate

soil properties under Aonla (*Emblica officinalis*) tree and open field condition following the application of different types of organic manure. The experiment comprised eight treatments: T₁ (no fertilizer, open field), T₂ (no fertilizer, under Aonla tree), T₃ (100% farmyard manure (FYM), open field), T₄ (100% FYM, under Aonla tree), T₅ (100% vermicompost, open field), T₆ (100% vermicompost, under Aonla tree), T₇ (50% FYM + 50% vermicompost, open field), and T₈ (50% FYM + 50% vermicompost, under Aonla tree), arranged in a Randomized Block Design with three replications. Among the treatments, T₈ (50% FYM + 50% vermicompost under Aonla tree) showed the most significant improvement in soil quality. Overall, soil health was better under Aonla tree compared to open field condition. The findings suggest that integrating FYM and vermicompost application in Aonla cultivation can effectively enhance soil health, offering a sustainable practice for farmers.

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INTRODUCTION

Soil fertility is a dynamic natural attribute that evolves under the influence of both natural processes and human activities. As the global population continues to rise, human intervention in ecosystems to meet the increasing demand for food and fiber exerts mount-

ing pressure on soils to supply essential nutrients. Continuous cropping aimed at maximizing yields significantly depletes soil nutrients. Moreover, the imbalanced and insufficient use of chemical fertilizers, improper irrigation practices and unsustainable agricultural techniques further accelerate the decline in soil quality (Singh *et al.* 2018). The application of organic manure plays a crucial role in improving soil biological properties by enhancing microbial abundance, diversity and activity, thereby contributing to overall soil health. By providing a rich source of organic matter, nutrients and energy, organic manure supports the growth of beneficial microbial communities, which are vital for nutrient cycling, organic matter turnover, and overall soil ecosystem functioning. Increased microbial diversity and activity lead to improved soil structure, greater nutrient availability, and enhanced disease suppression, collectively boosting soil fertility, resilience and sustainability (Verma *et al.* 2024).

In eastern Uttar Pradesh, rice predominates as the main crop during the *kharif* season, while wheat is dominant in the *rabi* season. A thorough understanding of the region's soil types, their distribution, constraints and potential is essential for effective soil management to enhance crop productivity and yields (Seema *et al.* 2021). The intensification of agricultural activities exerts increasing pressure on soils, often resulting in soil degradation and contamination (Marín-Pimentel *et al.* 2023). Protecting soil resources is critical to ensuring food security and sustaining life on Earth. Sustainable soil management is a fundamental pillar of agricultural sustainability. Globally, agriculture occupies around 5000 million hectares (Mha), approximately one-third of the Earth's land surface (Burbano-Orjuela 2016). However, about 1660 Mha are affected by soil degradation processes such as erosion, nutrient depletion and salinization (FAO 2021). Soil analysis remains a vital tool for assessing soil potential, fertility status, and nutrient availability (Lizcano *et al.* 2017). Soil is a cornerstone of agro-ecosystem sustainability, with its productivity largely dependent on its capacity to supply essential nutrients to crops (Singh *et al.* 2016). High soil quality is therefore indispensable for sustainable agriculture, influencing crop yields, ecological balance and overall land health.

Perennial trees like Aonla (*Emblica officinalis*), commonly known as Indian gooseberry, significantly enhance soil quality through their contributions to litter fall, root activity, and microclimate regulation (Das *et al.* 2011). Aonla is widely cultivated in various Indian states, including Uttar Pradesh, Uttarakhand, Gujarat, Maharashtra, Rajasthan, Tamil Nadu, Andhra Pradesh, Karnataka, Bihar, Haryana, Madhya Pradesh and West Bengal. In Uttar Pradesh, its cultivation is particularly prominent in the eastern region. Over the past two decades, there has been a substantial expansion in Aonla cultivation across India, especially on previously unproductive wastelands. This expansion has led to more efficient resource utilization, higher farm incomes, improved nutritional security, increased employment opportunities and the rehabilitation of degraded lands (Singh *et al.* 2019).

Despite these advancements, limited research has been conducted to assess the impact of Aonla trees on soil properties in this region. Understanding how Aonla cultivation influences soil health is crucial for developing better land management practices and optimizing the benefits of tree-based farming systems. This study aims to evaluate soil properties under Aonla plantations, contributing to the broader knowledge needed for promoting sustainable agriculture and preventing soil degradation. The insights gained could guide strategies to enhance soil fertility management and improve the long-term productivity and sustainability of agricultural land.

MATERIALS AND METHODS

The field experiment was carried out at the Main Experimental Station (MES) for Agroforestry, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India. The site is located at 26°33'25" N latitude and 81°50'56" E longitude, with an elevation of 113 meters above mean sea level.

The experiment involved two main factors: Fertilizer type and environmental condition. Four fertilizer treatments were applied: F₁ – no fertilizer (control), F₂ – 100% farmyard manure (FYM), F₃ – 100% vermicompost and F₄ – a 50 : 50 combination of FYM and vermicompost. These treatments were tested un-

der two conditions: Open field (C_1) and under Aonla (*Emblica officinalis*) trees (C_2), resulting in a total of eight treatment combinations: $T_1 - F_1$ in open field, $T_2 - F_1$ under Aonla tree, $T_3 - F_2$ in open field, $T_4 - F_2$ under Aonla tree, $T_5 - F_3$ in open field, $T_6 - F_3$ under Aonla tree, $T_7 - F_4$ in open field, and $T_8 - F_4$ under Aonla tree. A Factorial Randomized Block Design (FRBD) was used to structure the experiment.

To evaluate the soil properties, a total of 24 soil samples—one from each experimental plot were collected from both open field areas and beneath Aonla trees. The samples were initially air-dried in the shade and then crushed to break up clods. Afterward, they were sieved through a 2 mm mesh and stored in polyethylene bags for further analysis. Soil pH and electrical conductivity (EC) were measured using the soil-water suspension method as described by Jackson (1958). Soil organic carbon (%) and organic matter (%) were determined following the volumetric method by Walkley and Black (1934). Available nitrogen (kg ha^{-1}) and phosphorus (kg ha^{-1}) were estimated using the alkaline permanganate method (Subbiah and Asija 1956) and the colorimetric method (Olsen *et al.* 1954), respectively. Available potassium (kg ha^{-1}) and available sulfur (mg kg^{-1}) were determined using the ammonium acetate extraction method (Merwin and Peech 1951) and the calcium chloride extraction method (Williams and Steinberg 1959), respectively.

The data collected for all parameters from three replications of the experimental plots were subjected to statistical analysis using the Randomized Block Design (RBD) with two factors—fertilizer and growing condition—as well as their interaction. Analysis of variance (ANOVA) was performed at a 5% level of significance using the OPSTAT online agricultural data analysis tool, developed by O.P. Sheoran, Programmer, Computer Section, Chaudhary Charan Singh Haryana Agricultural University, Hisar, India.

RESULTS

Soil pH and soil electrical conductivity (EC):

The data on soil pH and EC are presented in Table 1. Statistical analysis revealed significant effects of fertilizer, condition (under Aonla tree vs. open field), and their interaction (fertilizer \times condition)

on soil pH and EC, with the exception that soil pH was not significantly influenced by condition and the interaction between fertilizer and condition. Across treatments, soil pH ranged from 7.803 to 8.550, and soil EC ranged from 0.224 to 0.283 dS/m. Among the fertilizers, the lowest soil pH (7.857) and EC (0.225 dS/m) were recorded under F_4 (50% FYM + 50% vermicompost), whereas the highest soil pH (8.510) and EC (0.279 dS/m) were observed in F_1 (no fertilizer). With respect to conditions, soil EC was significantly lower under the Aonla tree (0.247 dS/m) compared to the open condition (0.254 dS/m). Among treatment combinations, the lowest soil EC (0.224 dS/m) was recorded in T_8 (F_4 under Aonla tree), which was statistically at par with T_7 (F_4 in open condition), while the highest soil EC (0.283 dS/m) was observed in T_1 (F_1 under open condition).

Soil organic carbon and organic matter: Data on soil organic carbon (SOC) and soil organic matter (SOM), presented in Table 2, revealed significant differences due to fertilizer, condition, and their interaction. SOC values ranged from 0.285% to 0.363%, while SOM ranged from 0.491% to 0.626%. With respect to fertilizers, the highest SOC (0.361%) and SOM (0.623%) were recorded under F_4 (50% FYM + 50% vermicompost), while the lowest values for SOC (0.289%) and SOM (0.498%) were found in F_1 (no fertilizer). The soil beneath the Aonla tree showed a notable increase in SOC and SOM, with values of 0.331% and 0.571% respectively, compared to 0.322% (SOC) and 0.554% (SOM) observed under open condition. Among the treatment combinations, T_8 (F_4 under Aonla tree) recorded the highest SOC (0.363%) and SOM (0.626%), while the lowest values were recorded in T_1 (F_1 in open condition) with SOC (0.285%) and SOM (0.491%).

Soil available nitrogen and phosphorus:

Data on soil available nitrogen and phosphorus is presented in Table 3. Significant differences were observed due to the effect fertilizer, condition and their interaction, except for the interaction effect on soil phosphorus, which was not significant. Soil available nitrogen ranged from 152.748 to 167.619 kg ha^{-1} and phosphorus from 16.479 to 19.962 kg ha^{-1} . The highest values of available nitrogen (167.495 kg ha^{-1}) and phosphorus (19.844 kg ha^{-1}) were obtained with F_4 ,

Table 1. Effect of different organic manures on soil pH and electrical conductivity (EC).

Fertilizers (F)	Soil pH			Soil EC (dS/m)		
	Conditions (C)			Conditions (C)		
	Open (C ₁)	Aonla (C ₂)	Mean (F)	Open (C ₁)	Aonla (C ₂)	Mean (F)
No fertilizer (F ₁)	8.470	8.550	8.510	0.283	0.275	0.279
100% FYM (F ₂)	8.430	8.345	8.388	0.261	0.256	0.259
100% vermicompost (F ₃)	8.197	8.082	8.139	0.245	0.232	0.238
50% FYM + 50% vermicompost (F ₄)	7.910	7.803	7.857	0.227	0.224	0.225
Mean (C)	8.252	8.195		0.254	0.247	
Factors	F	C	F × C	F	C	F × C
CD (5%)	0.119	NS	NS	0.003	0.002	0.004

Table 2. Effect of different organic manures on soil organic carbon (SOC) and soil organic matter (SOM).

Fertilizers (F)	Soil organic carbon (%)			Soil organic matter (%)		
	Conditions (C)			Conditions (C)		
	Open (C ₁)	Aonla (C ₂)	Mean (F)	Open (C ₁)	Aonla (C ₂)	Mean (F)
No fertilizer (F ₁)	0.285	0.293	0.289	0.491	0.505	0.498
100% FYM (F ₂)	0.306	0.324	0.315	0.528	0.558	0.543
100% vermicompost (F ₃)	0.335	0.346	0.341	0.578	0.596	0.587
50% FYM + 50% vermicompost (F ₄)	0.359	0.363	0.361	0.619	0.626	0.623
Mean (C)	0.322	0.331		0.554	0.571	
Factors	F	C	F × C	F	C	F × C
CD (5%)	0.002	0.001	0.003	0.004	0.003	0.005

whereas the lowest were observed in F₁ (153.782 kg ha⁻¹ nitrogen and 16.666 kg ha⁻¹ phosphorus). Under Aonla tree, available nitrogen (162.496 kg ha⁻¹) and phosphorus (18.410 kg ha⁻¹) were higher than in open conditions (nitrogen: 160.443 kg ha⁻¹, phosphorus: 18.057 kg ha⁻¹). Among treatment combinations, T₈ (F₄ under Aonla tree) recorded the maximum available nitrogen (167.619 kg ha⁻¹), statistically at

Table 3. Effect of different organic manures on soil available nitrogen and phosphorus.

Fertilizers (F)	Soil available nitrogen (kg/ha)			Soil available phosphorus (kg/ha)		
	Conditions (C)			Conditions (C)		
	Open (C ₁)	Aonla (C ₂)	Mean (F)	Open (C ₁)	Aonla (C ₂)	Mean (F)
No fertilizer (F ₁)	152.748	154.817	153.782	16.479	16.854	16.666
100% FYM (F ₂)	157.821	162.170	159.996	17.546	17.956	17.751
100% vermicompost (F ₃)	163.832	165.375	164.604	18.475	18.871	18.673
50% FYM + 50% vermicompost (F ₄)	167.370	167.619	167.495	19.726	19.962	19.844
Mean (C)	160.443	162.496		18.057	18.410	
Factors	F	C	F × C	F	C	F × C
CD (5%)	0.391	0.276	0.553	0.07	0.05	NS

Table 4. Effect of different organic manures on soil available potassium and sulfur.

Fertilizers (F)	Soil available potassium (kg/ha) Conditions (C)			Soil available sulfur (mg kg ⁻¹) Conditions (C)		
	Open (C ₁)	Aonla (C ₂)	Mean (F)	Open (C ₁)	Aonla (C ₂)	Mean (F)
No fertilizer (F ₁)	184.471	186.527	185.499	7.255	7.861	7.558
100% FYM (F ₂)	188.681	190.629	189.655	8.297	8.560	8.428
100% vermicompost (F ₃)	192.616	194.580	193.598	8.856	9.418	9.137
50% FYM + 50% vermicompost (F ₄)	197.220	199.806	198.513	10.693	11.531	11.112
Mean (C)	190.747	192.886		8.775	9.343	
Factors	F	C	F × C	F	C	F × C
CD (5%)	0.206	0.146	0.291	0.136	0.096	0.192

par to T₇ (F₄ in open condition), while the minimum nitrogen (152.748 kg ha⁻¹) was observed in T₁ (F₁ in open condition).

Soil available potassium and sulfur: The results for soil available potassium and sulfur are presented in Table 4. Significant variations were observed due to fertilizer application, condition and their interaction. The highest available potassium (198.513 kg ha⁻¹) and sulfur (11.112 mg kg⁻¹) were recorded under F₄, whereas the lowest values (185.499 kg ha⁻¹ potassium and 7.558 mg kg⁻¹ sulfur) were found in F₁. Soil under the Aonla tree showed higher potassium (192.886 kg ha⁻¹) and sulfur (9.343 mg kg⁻¹) compared to the open field, which recorded potassium at 190.747 kg ha⁻¹ and sulfur at 8.994 mg kg⁻¹. Among treatment combinations, T₈ (F₄ under Aonla tree) recorded the highest values for potassium (199.806 kg ha⁻¹) and sulfur (11.531 mg kg⁻¹), whereas T₁ (F₁ in open condition) recorded the lowest values (potassium: 184.471 kg ha⁻¹, sulfur: 7.255 mg/kg⁻¹).

DISCUSSION

Soil pH and electrical conductivity (EC): The results indicate that both soil pH and EC were significantly influenced by fertilizer, condition and their interaction, except in the case of soil pH where condition and interaction effects were not significant. This aligns with previous findings that soil chemical properties, including pH and EC, are strongly influenced by organic amendments and localized environmental conditions (Singh *et al.* 2024). The

lowest soil pH and EC values were recorded under the F₄ treatment (50% FYM + 50% vermicompost) which might be due to the synergistic effect of FYM and vermicompost. Aulakh *et al.* (2022) stated that organic inputs like FYM and vermicompost are known to buffer soil pH and improve salt balance, thereby reducing EC. Soils under the Aonla tree canopy exhibited significantly lower EC compared to open conditions, likely due to enhanced microbial activity and organic matter input through leaf litter, which has a moderating effect on ion accumulation (Korwar *et al.* 2006). Notably, the lowest EC was observed in T₈ (F₄ under Aonla tree), underscoring the synergistic benefits of organic amendments under tree-based agroecosystems.

Soil organic carbon and organic matter: The application of fertilizers, especially the combined use of FYM and vermicompost (F₄), significantly improved soil organic carbon (SOC) and soil organic matter (SOM) content. This is consistent with several studies emphasizing the role of organic fertilizers in improving carbon sequestration and soil quality (Pandiselvi *et al.* 2017). The maximum SOC and SOM were recorded under the T₈ treatment, suggesting enhanced organic matter accumulation under the Aonla tree. Trees contribute to soil organic matter through litter fall and root biomass, which might explain the significantly higher SOC and SOM values in the tree-based condition compared to the open area (Adak *et al.* 2018). The improved organic matter under F₄ treatments is attributed to the higher humus formation potential of vermicompost and the

slow decomposition rate of FYM, which contribute to long-term soil fertility (Das *et al.* 2015).

Soil available nitrogen and phosphorus: Significant variations in soil available nitrogen and phosphorus were observed across fertilizer, condition, and their interaction (except for phosphorus, where interaction effects were not significant). F₄ recorded the highest values for both nutrients, highlighting the nutrient-releasing potential of organic inputs. Vermicompost, in particular, is a rich source of plant-available nitrogen and phosphorus, and its integration with FYM ensures a balanced and sustained release of nutrients (Yadav and Garg 2011).

The higher nutrient levels under the Aonla tree condition might be attributed to increased microbial activity and organic inputs from tree litter, which enhance nutrient mineralization (Celentano *et al.* 2020). The superior performance of the T₈ treatment in terms of nitrogen and phosphorus availability again supports the combined role of organic amendments and tree based system in improving soil nutrient status.

Soil available potassium and sulfur: Available potassium and sulfur were significantly enhanced by organic fertilizer, condition and their combination. F₄ treatment resulted in the highest potassium and sulfur concentrations, consistent with earlier studies that report improved nutrient availability following organic inputs due to increased cation exchange capacity and microbial activity (Srinivasarao *et al.* 2021). Notably, soils under the Aonla tree exhibited higher nutrient content than open field conditions, possibly due to reduced erosion, better moisture retention and enhanced microbial cycling under canopy cover (Pinho *et al.* 2012). Among the treatment combinations, the highest values observed under the T₈ treatment again reinforce the advantage of integrating tree-based systems with organic nutrient management strategies.

CONCLUSION

The semi-arid region of Ayodhya, Uttar Pradesh, faces significant soil health challenges, notably declining fertility and the pressing need for sustainable agricultural practices. Although the soils

are generally well-suited for horticultural crops, targeted strategies are essential to enhance soil health and improve productivity. This study was conducted in the semi-arid areas of Ayodhya to assess soil properties under Aonla plantations and open field conditions using various combinations of organic manures. The findings demonstrated that the cultivation of Aonla with the combined application of 50% FYM and 50% vermicompost, significantly improved soil fertility. While this study specifically evaluated the effects of FYM and vermicompost, further research into the application of other organic manures, such as sheep, goat and poultry manure, is recommended to fully explore their potential benefits for soil health improvement. In conclusion, the results strongly suggest that farmers should prioritize the use of organic manures over chemical fertilizers to promote long-term soil health and ensure sustainable agricultural productivity.

REFERENCES

- Adak, T. A., Rajan, S. H., & Singh, V. K. (2018). Dynamics of soil and tree carbon storage in different agroforestry/tree based land use systems. *Journal of Agricultural Physics*, 18 (1), 127–134.
- Aulakh, C. S., Sharma, S., Thakur, M., & Kaur, P. (2022). A review of the influences of organic farming on soil quality, crop productivity and produce quality. *Journal of Plant Nutrition*, 45 (12), 1884–1905.
- Burbano-Orjuela, H. (2016). The soil and its relationship with ecosystem services and food security. *Revista de Ciencias Agrícolas*, 33 (2), 117–124.
- Celentano, D., Rousseau, G. X., Paixão, L. S., Lourenço, F., Cardozo, E. G., Rodrigues, T. O., e Silva, H. R., Medina, J., de Sousa, T. M., Rocha, A. E., de Oliveira, & Reis, F. (2020). Carbon sequestration and nutrient cycling in agroforestry systems on degraded soils of Eastern Amazon, Brazil. *Agroforestry Systems*, 94, 1781–1792.
- Das, D., Dwivedi, B. S., Meena, M. C., Singh, V. K., & Tiwari, K. N. (2015). Integrated nutrient management for improving soil health and crop productivity. *Indian Journal of Fertilizers*, 11 (4), 64–83.
- Das, D. K., Chaturvedi, O. P., Jha, R. K., & Kumar, R. (2011). Yield, soil health and economics of aonla (*Emblica officinalis* Gaertn.)-based agri-horticultural systems in eastern India. *Current Science*, 25, 786–790.
- FAO. (2021). The state of the world's land and water resources for food and agriculture. Food and Agriculture Organization, Rome, Italy.
- Jackson, M. L. (1958). Soil Chemical Analysis. Practice Hall of India, New Delhi.
- Korwar, G. R., Pratibha, G., Ravi, V., & Palanikumar, D. (2006).

- Influence of organics and inorganics on growth, yield of aonla (*Emblica officinalis*) and soil quality in semi-arid-tropics. *The Indian Journal of Agricultural Sciences*, 76 (8), 457—461.
- Lizcano, R., Olivera, D., Saavedra, D., Machado, L., Rolando, E., Moreno, M. F., & Flórez, M. F. (2017). Soil sampling, laboratory techniques and interpretation of soil analysis. La Angostura Agroindustrial Training Center (SENA).
- Marín-Pimentel, G. E., Rueda-Saa, G., & Menjivar-Flores, J. C. (2023). Evaluation of physico-chemical properties in agricultural soils on the flat and piedmont areas of Valle del Cauca, Colombia with emphasis on degradation. *Environmental Earth Sciences*, 82 (7), 157.
- Merwin, H. D., & Peech, M. (1951). Exchangeability of soil potassium in the sand, silt and clay fractions, as influenced by the nature of the complementary exchangeable cations. *Soil Science Society of America Journal*, 15, 125—128.
- Olsen, S., Cole, C., Watanabe, F., & Dean, L. (1954). Estimation of available phosphorus in soil by extraction with sodium bicarbonate. United State Department of Agriculture, USA.
- Pandiselvi, T., Jeyajothiand, R., & Kandeshwari, M. (2017). Organic nutrient management a way to improve soil fertility and sustainable agriculture-a review. *International Journal of Advancement in Life Sciences Research*, 10 (2), 175—181.
- Pinho, R. C., Miller, R. P., & Alfaia, S. S. (2012). Agroforestry and the improvement of soil fertility: A view from Amazonia. *Applied and Environmental Soil Science*, 2012 (1), 616383.
- Seema Ghosh, A. K., Yadav, S., Singh, P., & Thakur, A. (2021). Characterization and fertility assessment of soils of Mirzapur district of Eastern Uttar Pradesh for sustainable land use planning. *Journal of the Indian Society of Soil Science*, 69 (4), 347—353.
- Singh, A. K., Singh, S., Saroj, P. L., Mishra, D. S., Singh, P. P., & Singh, R. K. (2019). Aonla (*Emblica officinalis*) in India: A review of its improvement, production and diversified uses. *The Indian Journal of Agricultural Sciences*, 89 (11), 1773—1781.
- Singh, N. K., Sachan, K., Manoj, B. P., Panotra, N., & Katiyar, D. (2024). Building soil health and fertility through organic amendments and practices: A review. *Asian Journal of Soil Science and Plant Nutrition*, 10 (1), 175—197.
- Singh, S. P., Singh, S., Kumar, A., & Kumar, R. (2018). Soil fertility evaluation for macronutrients using parkers nutrient index approach in some soils of Varanasi district of Eastern Utter Pradesh, India. *Indian Journal of Pure & Applied Biosciences*, 6 (5), 542—548.
- Singh, Y. V., Singh, S. K., Sahi, S. K., Verma, S. K., Yadav, R. N., & Singh, P. K. (2016). Evaluation of soil fertility status from Milkipur village, Arajiline block, Varanasi, district, Uttar Pradesh, in relation to Soil characteristics. *Journal of Pure and Applied Microbiology*, 10 (2), 1455—1461.
- Srinivasarao, C., Singh, S. P., Kundu, S., Abrol, V., Lal, R., Abhilash, P. C., Chary, G. R., Thakur, P. B., Prasad, J. V., & Venkateswarlu, B. (2021). Integrated nutrient management improves soil organic matter and agronomic sustainability of semi-arid rainfed inceptisols of the Indo-Gangetic Plains. *Journal of Plant Nutrition and Soil Science*, 184 (5), 562—572.
- Subbiah, B. V., & Asija, G. L. (1956). A rapid method for estimation of available N in soil. *Current Science*, 25, 259—260.
- Verma, S., Pradhan, S. S., Singh, A., & Kushuwaha, M. (2024). Effect of organic manure on different soil properties: A review. *International Journal of Plant & Soil Science*, 36 (5), 182—187.
- Walkley, A., & Black, C. (1934). Determination of organic matter in the soil by chronic acid digestion. *Journal of Soil Science*, 63, 251—264.
- Williams, C. H., & Steinberg, A. (1959). Soil sulphate fractions as chemical indices of available sulfur in some Australian soils. *Australian Journal of Agricultural Research*, 10, 340—352.
- Yadav, A., & Garg, V. K. (2011). Recycling of organic wastes by employing *Eisenia fetida*. *Bioresources Technology*, 102 (3), 2874—2880.