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Depth-Wise Assessment of Physico-Chemical Properties of Soils under KVK Thakurdwara, Moradabad, Uttar Pradesh

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Abstract
The present investigation was conducted at KVK Thakurdwara, Moradabad, Uttar Pradesh (29°19' N, 78°86' E, 240 ft above mean sea level) to assess the physico-chemical properties, nutrient availability and fertility status of soil at two depths, that is 0-15 and 15-30 cm. Soil samples from 19 plots were analysed for texture, bulk density, particle density, porosity, pH, electrical conductivity (EC), organic carbon (OC), available N, P, K and S and DTPA-extractable Fe, Mn, Cu and Zn. All the samples were classified as sandy loam, with surface soil containing 62-74% sand, 18-28% silt and 4-18% clay. Soil pH ranged from 7.14-7.35 and 7.25-7.40, while EC ranged from 0.11-0.20 and 0.15-0.33 dSm^{-1} in surface and subsurface soils, respectively. Organic carbon ranged from 0.26-0.53% in surface and 0.14-0.43% in subsurface soil. Available N was low, P was medium, K was predominantly medium and S was medium in both soil depths. Among micronutrients, Cu was sufficient in all samples, Zn was sufficient in all surface samples and 66.67% of subsurface samples, while Fe ranged from sufficient to marginal and Mn was more than sufficient. Organic carbon showed a strong positive correlation with available N in surface (r = 0.971) and subsurface (r = 0.972) soils. Available Fe also exhibited a strong positive correlation with Zn in surface (r = 0.843) and subsurface (r = 0.815) soils. Overall, the soils exhibited favorable physical conditions but relatively low organic carbon and nitrogen status, highlighting the need for balanced fertilization and integrated nutrient management for sustaining soil fertility and crop productivity.
Keywords: *Physico-chemical properties, Nutrient availability, Correlation and KVK Thakurdwara*

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I. INTRODUCTION

Soil is a fundamental resource for agricultural production and provides the physical medium, water and nutrients required for plant growth. Soil fertility is governed by the interaction of its physical, chemical and biological properties, including texture, bulk density, porosity, pH, electrical conductivity (EC), organic carbon (OC), available macronutrients and micronutrients. These properties collectively regulate water retention, aeration, nutrient transformation, mobility and plant uptake. Therefore, systematic assessment of soil properties is essential for identifying fertility constraints and developing site-specific nutrient-management strategies (Chakraborty *et al.,* 2024). Organic carbon is an important indicator of soil quality because it contributes to soil aggregation, nutrient cycling, microbial activity and nutrient retention. Declining organic carbon under continuous cultivation can adversely affect the nutrient-supplying capacity and resilience of agricultural soils. Recent studies in India have reported considerable variability in soil organic carbon and nutrient availability and emphasized the importance of integrated soil-health assessment for sustainable crop production (Poonia *et al*., 2024). The availability of macronutrients, particularly nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) is equally important for maintaining crop productivity. A recent assessment of agricultural soils across eight administrative blocks of Moradabad district reported organic carbon values ranging from 0.26-0.51%, available nitrogen from 71.24-103.56 kg ha^{-1}, available phosphorus from 13.66-23.50 kg ha^{-1} and available potassium from 159.10-217.91 kg ha^{-1}, indicating considerable variability in the fertility status of soils across the district (Sharma *et al*., 2024). Micronutrients such as zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu), although required in smaller quantities, are essential for enzyme activation, photosynthesis, protein synthesis and several physiological processes in plants. Their availability is strongly influenced by soil pH, organic carbon, texture and interactions with other nutrients. The importance of micronutrient assessment in India is highlighted by a large-scale study involving 242,827 soil samples from 615 districts across 28 states, which reported deficiencies of sulphur, zinc and boron in 58.6%, 51.2% and 44.7% of the sampled soils, respectively, while Fe, Cu and Mn deficiencies occurred in 19.2%, 11.4% and 17.4% of soils (Shukla *et al*., 2021). More recently, Sahay *et al*., (2024) reported Zn deficiency in 39.5% of soils sampled from Hasanganj and Auras blocks of Unnao district, Uttar Pradesh, demonstrating the continuing importance of micronutrient evaluation in the state. Khokhar *et al*., (2024) further emphasized the importance of soil Zn assessment in India because Zn availability has implications for both crop productivity and nutritional quality.

Moradabad district is situated in the Indo-Gangetic Plain of Uttar Pradesh and is predominantly characterized by alluvial soils with loam to sandy-loam texture. The soils of the region exhibit variation in their physico-chemical properties with depth, land use and management practices. Recent assessment of agricultural soils across different blocks of Moradabad reported variation in organic carbon, available nitrogen, phosphorus and potassium, indicating spatial variability in soil fertility within the district (Sharma *et al.,* 2024). The need for comprehensive soil assessment is particularly relevant in this intensively cultivated region, where continuous nutrient removal and changing management practices can influence soil fertility and nutrient availability. A recent study at KVK Muzaffarnagar, Uttar Pradesh, also reported predominantly sandy-loam, neutral to slightly alkaline and non-saline soils with low organic carbon and available nitrogen, highlighting the importance of systematic soil fertility assessment in western Uttar Pradesh (Palani Renuka *et al.,* 2024). Therefore, the present investigation was undertaken to assess the physico-chemical properties and available macro and micronutrients at different soil depths, determine the relationships among selected soil properties and evaluate the fertility status of soils of KVK Thakurdwara, Moradabad, Uttar Pradesh.

II. MATERIALS AND METHODS

Study Area and Soil Sampling: The present investigation was conducted at the farm of Krishi Vigyan Kendra (KVK), Thakurdwara, Moradabad, Uttar Pradesh (29°19′ N, 78°86′ E, 240 ft above mean sea level). Soil samples were collected during 2025 from representative plots of the KVK farm using GPS. A total of 19 soil samples were collected from two depths, that is 0-15 cm (surface soil) and 15-30 cm (sub-surface soil). Surface litter and contaminated soil were carefully removed using a khurpi, followed by opening a V-shaped pit for collection of representative soil samples from the respective depths. The collected samples were properly labelled and brought to the laboratory of the Department of Soil Science, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, where they were processed and prepared for analysis following standard procedures. The soil samples were analysed for physical properties, that is soil texture, bulk density, particle density and porosity and chemical properties, including pH, electrical conductivity (EC), organic carbon (OC), available N, P, K and S and DTPA-extractable Fe, Mn, Cu and Zn.

Physico-Chemical Analysis*:* The processed soil samples were analysed for their physico-chemical properties and nutrient status. Soil texture, bulk density, particle density and porosity were determined by the methods of Bouyoucos (1962), Piper (1966) and Blake and Hartge (1986), respectively. Soil pH and electrical conductivity (EC) were determined in a 1:2.5 soil:water suspension following Jackson (1973), organic carbon (Walkley and Black, 1934) method. Available N, P, K and S were estimated by the methods of Subbiah and Asija (1956), Olsen *et al.,* (1954), Toth and Prince (1949) and Chesnin and Yien (1951), respectively. DTPA-extractable Zn, Fe, Mn and Cu were determined using the method of Lindsay and Norvell (1978) through atomic absorption spectrophotometry having measurable limit of 0.01 ppm (mg L^{-1}).

Statistical analysis: Pearson's correlation coefficient was used to determine the direction and strength of association between selected physical, textural and chemical properties of the soil. (Pearson, 1895).

III. RESULTS AND DISCUSSION

Physico-chemical properties of soil: The physico-chemical properties of soils of KVK Thakurdwara are presented in Tables 1 and 2. All 19 samples were sandy loam, with surface-soil sand, silt and clay ranging from 62-74%, 18-28% and 4-18%, respectively. The dominance of sand indicates the relatively coarse nature of the soils, which generally favours drainage and aeration but may reduce water and nutrient retention. Similar sandy-loam soils have been reported in north-western Uttar Pradesh (Chakraborty *et al*., 2024), while Sharma *et al.* (2024) also reported considerable variability in the physico-chemical properties of agricultural soils of Moradabad. Bulk density ranged from 1.26-1.46 Mgm^{-3} in surface and 1.39-1.53 Mgm^{-3} in subsurface soil, whereas particle density ranged from 2.22-2.50 and 2.33-2.57 Mgm^{-3}, respectively. The increase in bulk density with depth may be attributed to reduced organic matter, greater overburden pressure and compaction in the subsurface layer. Consequently, porosity decreased from 38.72-46.66% in surface soil to 37.13-43.30% in subsurface soil. The inverse relationship between bulk density and porosity indicates that increasing compaction with depth reduced pore space. Similar depth-wise trends in bulk density and porosity have been reported in

Uttar Pradesh soils (Pandey *et al.*, 2024). Soil pH ranged from 7.14-7.35 in surface and 7.25-7.43 in subsurface soil, indicating neutral to slightly alkaline conditions. The slightly higher subsurface pH may be related to the downward movement and accumulation of basic cations. Comparable pH conditions have been reported in alluvial soils of north-western Uttar Pradesh and Moradabad (Chakraborty *et al.*, 2024). EC ranged from 0.11-0.20 and 0.15-0.33 dS m^{-1} in surface and subsurface soils, respectively, indicating non-saline conditions. Low EC values suggest limited soluble-salt accumulation and favourable conditions for crop growth, consistent with reports from Uttar Pradesh (Pandey *et al.*, 2024). Organic carbon ranged from 0.26-0.53% in surface and 0.14-0.43% in subsurface soil, showing a clear decline with depth. The higher surface OC is attributable to greater accumulation of crop residues, root biomass and organic inputs near the soil surface. Similar depth-wise decreases in OC have been reported in Moradabad and other parts of Uttar Pradesh (Sharma *et al.*, 2024). The relatively low OC status may have implications for nutrient cycling and long-term soil fertility. Overall, the soils were predominantly sandy loam, non-saline and neutral to slightly alkaline. The higher surface porosity and organic carbon and lower bulk density indicate comparatively favourable conditions in the surface layer, whereas the subsurface layer showed greater density and lower porosity.

Table 1: Depth-wise average values of physical properties of soils at KVK Thakurdwara

Plot No.	Soil textural class			Bulk density (Mg m^{-3})		Particle density (Mg m^{-3})		Porosity (%)	
	Sand	Silt	Clay	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	74	22	04	1.38	1.50	2.45	2.54	43.67	40.90
2	70	22	08	1.34	1.46	2.28	2.40	41.22	39.16
3	72	20	08	1.37	1.47	2.50	2.57	45.20	42.80
4	64	18	18	1.33	1.43	2.23	2.33	40.35	38.62
5	66	20	14	1.42	1.53	2.43	2.51	41.56	39.04
6	70	20	10	1.44	1.52	2.35	2.44	38.72	37.70
7	62	28	10	1.37	1.46	2.30	2.36	40.40	38.13
8	70	18	12	1.26	1.39	2.36	2.45	46.61	43.26
9	68	28	04	1.33	1.40	2.26	2.34	41.15	40.17
10	62	28	10	1.36	1.44	2.42	2.54	43.80	43.30
11	64	18	18	1.32	1.45	2.32	2.42	43.10	41.81
12	66	28	06	1.36	1.52	2.37	2.46	42.61	38.21
13	71	21	08	1.34	1.49	2.45	2.54	45.18	39.90
14	65	18	17	1.30	1.46	2.28	2.39	40.32	38.16
15	65	20	15	1.40	1.46	2.49	2.56	41.51	41.80
16	70	19	11	1.46	1.42	2.22	2.34	38.75	37.62
17	62	26	12	1.35	1.51	2.43	2.50	40.37	39.04
18	70	20	10	1.30	1.51	2.35	2.44	46.66	39.70
19	66	25	09	1.30	1.45	2.24	2.35	41.12	37.13

Table 2: Depth-wise average values of pH, EC and OC of soils at KVK Thakurdwara

Plot No.	pH		EC (dSm^{-1})		OC (%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	7.29	7.34	0.13	0.17	0.26	0.14
2	7.26	7.4	0.13	0.15	0.36	0.22
3	7.23	7.36	0.15	0.18	0.40	0.28
4	7.16	7.29	0.17	0.19	0.53	0.43
5	7.22	7.31	0.14	0.16	0.34	0.25
6	7.33	7.37	0.13	0.17	0.43	0.33
7	7.30	7.36	0.14	0.15	0.46	0.35

8	7.25	7.33	0.18	0.33	0.43	0.33
9	7.23	7.32	0.17	0.21	0.52	0.33
10	7.31	7.38	0.17	0.19	0.44	0.32
11	7.26	7.34	0.12	0.16	0.43	0.32
12	7.18	7.25	0.11	0.17	0.41	0.27
13	7.20	7.35	0.14	0.17	0.39	0.29
14	7.14	7.25	0.16	0.17	0.50	0.41
15	7.20	7.28	0.12	0.15	0.33	0.25
16	7.35	7.36	0.14	0.15	0.41	0.30
17	7.32	7.39	0.13	0.16	0.43	0.33
18	7.27	7.36	0.20	0.20	0.43	0.32
19	7.21	7.35	0.15	0.20	0.49	0.34

Available macronutrients: The available macronutrient status of the soils is presented in Figure 1 and 2. Available N ranged from 179.30-238.86 kg ha^{-1} in surface soil and 146.76-228.30 kg ha^{-1} in subsurface soil, with a general decline with depth. Higher surface N due to greater organic residue accumulation and mineralization. All samples were low in available N, indicating N as a major fertility constraint. Similar low N availability in western Uttar Pradesh soils was reported by Palani Renuka *et al.,* (2024). Available P ranged from 16.42-23.77 kg ha^{-1} in surface and 16.10-21.77 kg ha^{-1} in subsurface soil, with slightly higher values in the surface layer. All samples were medium in P, indicating moderate availability. The slight decline with depth due to P's low mobility and its greater accumulation in the surface through fertilizer application and organic matter recycling. Similar medium P status was reported in western Uttar Pradesh soils (Palani Renuka *et al.*, 2024). Available K ranged from 153.66-258.96 kg ha^{-1} in surface and 133.22-226.52 kg ha^{-1} in subsurface soil, with higher values in the surface layer. This attributed to crop residue recycling and greater nutrient inputs near the soil surface. Most samples were medium in K, while some subsurface samples were low. Similar depth-wise variation in available K was reported in Uttar Pradesh soils (Palani Renuka *et al.*, 2024). Available S ranged from 25.67-37.78 kg ha^{-1} in surface and 24.08-34.79 kg ha^{-1} in subsurface soil, with all samples categorized as medium. The slightly higher surface S may be due to greater organic matter and mineralization of organically bound S. Similar depth-wise variation in available S was reported in western Uttar Pradesh soils (Palani Renuka *et al.*, 2024). Overall, available N was the major fertility constraint, whereas P, K and S were predominantly medium. The decline in most nutrients with depth emphasizes the importance of maintaining surface-soil organic matter and adopting balanced nutrient management to sustain soil fertility.

Figure 1: Depth-wise average values of nitrogen and potassium of soils at KVK Thakurdwara

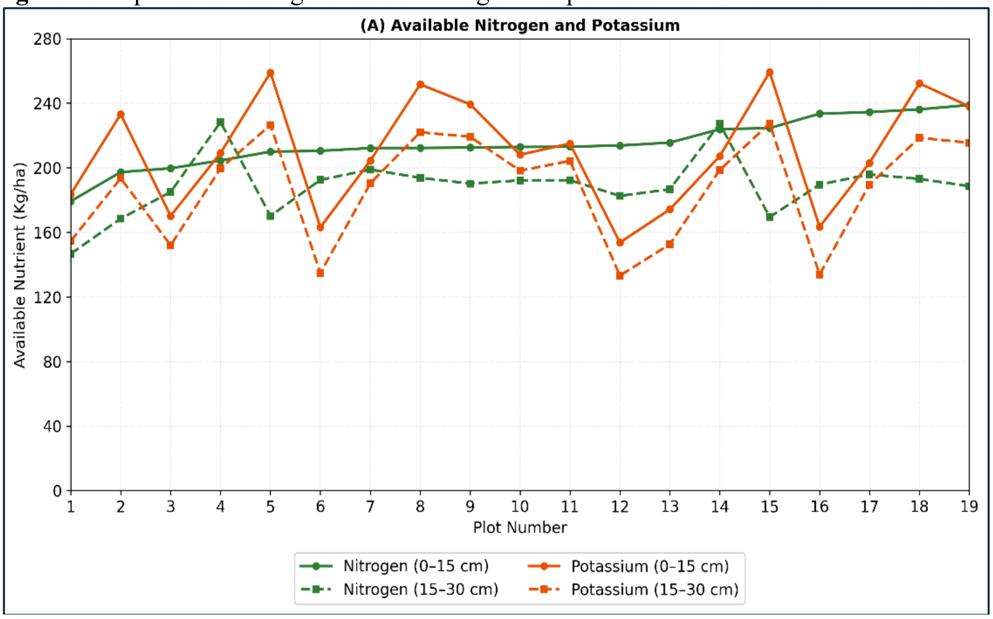
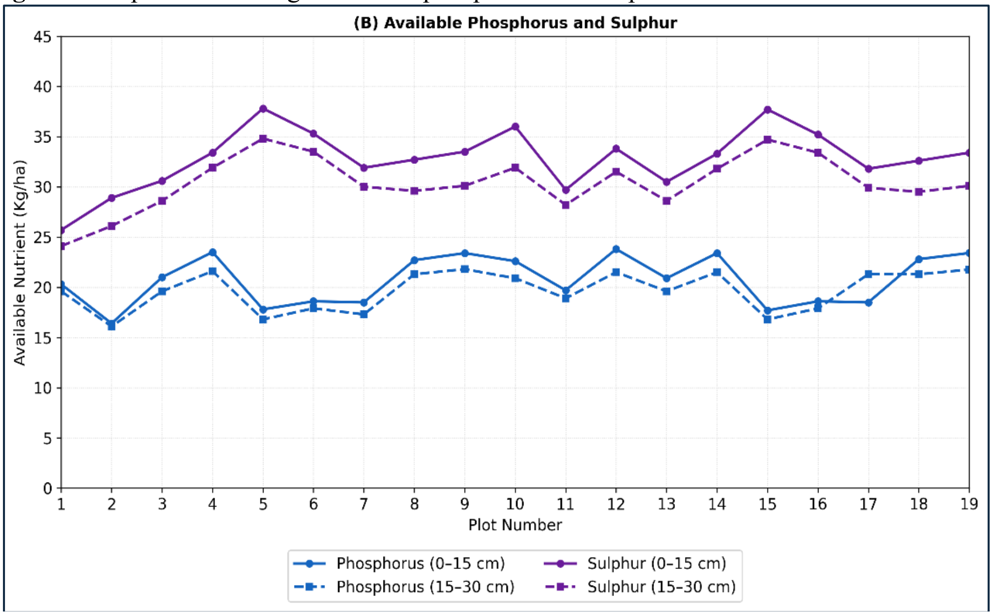


Figure 2: Depth-wise average values of phosphorus and sulphur of soils at KVK Thakurdwara



Available micronutrients: The DTPA-extractable micronutrient status of the soils is presented in figure 3 and 4. Available Cu ranged from 0.698-0.971 mg kg^{-1} in surface and 0.612-0.894 mg kg^{-1} in subsurface soil, while Fe ranged from 6.588-12.994 and 6.036-11.413 mg kg^{-1}, respectively, showing a general decline with depth. All samples were above the critical limit for Cu, whereas Fe was in the high category. Available Mn ranged from 13.44-19.46 mg kg^{-1} in surface and 12.38-18.55 mg kg^{-1} in subsurface soil, indicating sufficient to high availability. Zn ranged from 1.34-2.28 mg kg^{-1} in surface and 1.01-2.01 mg kg^{-1} in subsurface soil, with generally higher concentrations in surface soil. The higher surface micronutrient availability may be attributed to greater organic matter accumulation, biological cycling and micronutrient retention, consistent with the depth-wise distribution of organic carbon. Similar depth-wise variation in DTPA-extractable micronutrients was reported in the Indo-Gangetic Plain (Sharma *et al.,* 2024). Palani Renuka *et al.,* (2024) also reported considerable variation in DTPA-extractable Zn, Fe, Mn and Cu in nearby Muzaffarnagar soils, influenced by soil properties. Singh and Singh (2025) reported sufficient to high Zn and high Fe, Mn and Cu in soils of the Azamgarh division of Uttar Pradesh. Overall, KVK Thakurdwara soils showed adequate to high Fe, Mn and Cu and Zn above the critical level, although Zn exhibited greater spatial and depth-wise variation, suggesting the need for continued monitoring.

Figure 3: Depth-wise average values of zinc and copper of soils at KVK Thakurdwara

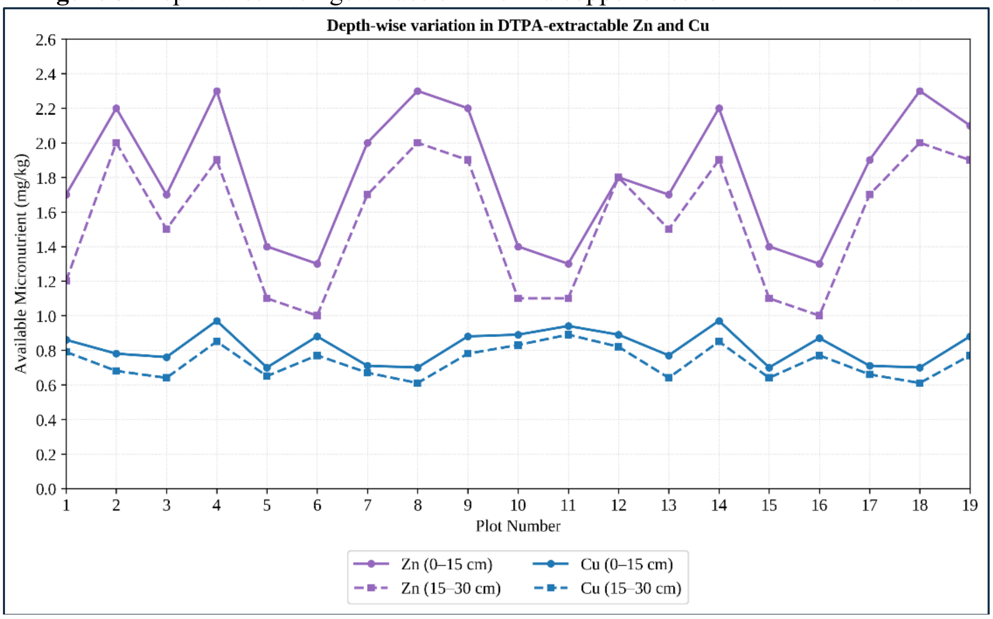
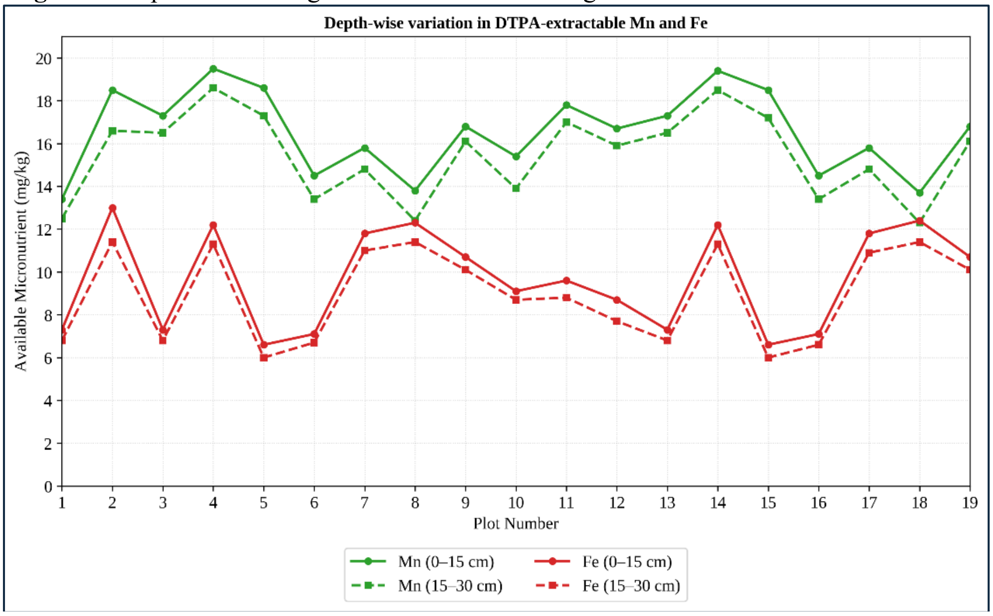


Figure 4: Depth-wise average values of iron and manganese of soils at KVK Thakurdwara



Correlation among soil available nutrients: Pearson correlation analysis revealed distinct relationships among soil properties and available nutrients at both depths (figure 5 and 6). Organic carbon showed a very strong positive correlation with available N in surface ($r = 0.971$) and subsurface ($r = 0.972$) soil, indicating the important role of organic matter in N mineralization and availability. Similar positive relationships of OC with available N, P and K were reported by Kumar *et al.,* (2021) in western Uttar Pradesh and by Kumawat *et al.,* (2024) for Uttar Pradesh soils. In surface soil, EC showed positive correlations with P ($r = 0.617$), Zn ($r = 0.567$), N ($r = 0.542$) and OC ($r = 0.538$), whereas pH showed negative relationships with most nutrients, particularly Mn ($r = -0.644$) and P ($r = -0.492$). In subsurface soil, OC remained strongly associated with N ($r = 0.972$), while Fe showed positive relationships with N ($r = 0.563$) and Zn ($r = 0.815$). The negative association of pH with several nutrients may be due to reduced nutrient solubility and availability under increasing alkalinity, particularly for micronutrients, as also reported by Maurya *et al.,* (2021) and Kumawat *et al.,* (2024). The strong positive association between Fe and Zn suggests their availability was influenced by common soil chemical and retention processes, consistent with findings from Uttar Pradesh and nearby Indo-Gangetic regions (Kumawat *et al.,* 2024). Overall, OC was an important soil property influencing nutrient availability, particularly N, while pH affected several macro and micronutrients. These relationships highlight the importance of maintaining soil organic matter and balanced nutrient management for sustaining soil fertility.

Figure 5: Pearson's correlation analysis at 0-15 cm depth

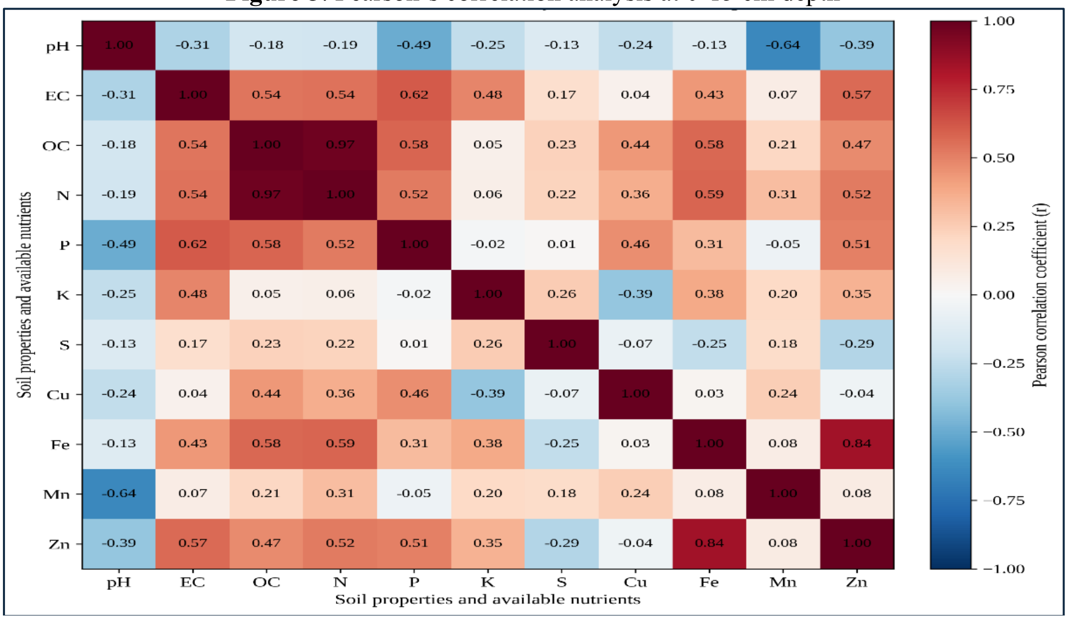
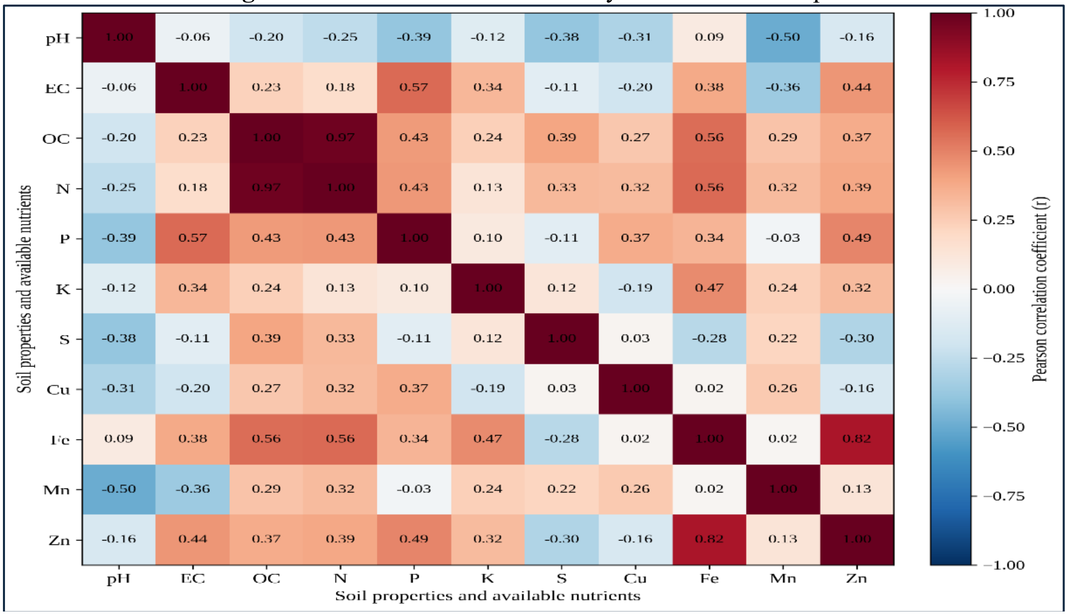


Figure 6: Pearson's correlation analysis at 15-30 cm depth



Nutrient index and fertility status of soil: Surface soil recorded an index value of 2.00 for all three nutrients, indicating medium fertility, whereas subsurface N declined to 1.00 (low) while P and K remained medium (2.00). The lower N status at depth may be associated with reduced organic carbon and mineralizable N. The nutrient index was calculated following Ravikumar and Somashekar (2013). Overall, the soils were sandy loam, neutral, non-saline and low to medium in fertility, with low organic carbon and N requiring greater attention, while P, K, S and most micronutrients were generally adequate

IV. CONCLUSION

From the assessment of the study, it can be concluded that the soils of KVK Thakurdwara, Moradabad, Uttar Pradesh, were predominantly sandy loam, neutral to slightly alkaline and non-saline, with generally favourable conditions for crop production. Available N was the major fertility constraint, while P, K and S were predominantly medium. DTPA-extractable Fe, Mn and Cu were adequate to high, whereas Zn remained above the critical level with greater depth-wise variation. Organic carbon was strongly associated with available N, while soil pH influenced the availability of several nutrients. Overall, the soils exhibited low-to-medium fertility, showing the need for improved organic matter management, balanced fertilization and regular soil testing to sustain soil fertility and productivity.

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Conflict of Interest

The authors declare that they do not have any competing interest.

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