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Evaluation of Soil Fertility Status Using Macro-, Micro-Nutrients and Nutrient Index Values in the KRISAT Farm, Tamil Nadu

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Abstract
A study was conducted to evaluate the fertility status of soils in the instructional farm of Krishna College of Agriculture and Technology (KRISAT), Usilampatti, Tamil Nadu, using macro- and micronutrient analysis and nutrient index values. Sixty-two geo-referenced surface soil samples (0–15 cm) collected from different survey numbers were analyzed for available nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and organic carbon following standard analytical procedures. Available nitrogen ranged from 50.0–71.4 kg ha^{-1}, phosphorus from 1.4–25.0 kg ha^{-1} and potassium from 52–265 kg ha^{-1}. DTPA-extractable Fe, Mn, Zn and Cu ranged from 2.44–8.73, 2.31–7.60, 0.34–1.21 and 0.16–1.92 mg kg^{-1}, respectively, while organic carbon ranged from 0.22–0.31%. Nutrient index values indicated low fertility for nitrogen, copper and organic carbon; low to medium fertility for phosphorus and potassium; and medium fertility for iron, manganese and zinc. The study highlights the need for site-specific nutrient management and integrated nutrient management practices to improve soil fertility, enhance fertilizer use efficiency and sustain crop productivity in the KRISAT farm.

Keywords: (KRISAT), nitrogen (N), phosphorus (P), potassium (K), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu)

Introduction

Soil is one of the most valuable natural resources that supports agricultural production and sustains ecosystem functions. Its capacity to supply essential plant nutrients determines crop productivity, nutrient use efficiency, and the long-term sustainability of agricultural systems. Soil fertility evaluation generally involves the determination of available macro-nutrients, including nitrogen (N), phosphorus (P), and potassium (K), together with essential micronutrients such as iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu). Organic carbon serves as a key indicator of soil quality because it influences nutrient cycling, microbial activity, aggregate stability, and moisture retention. Among the various approaches used to assess soil fertility, the Nutrient Index (NI) method is widely accepted because it provides a simple yet effective measure of the overall fertility status of a region or farm.Although numerous studies have evaluated soil fertility status at district and watershed scales, information on the spatial distribution of macro- and micronutrients at institutional farms remains limited. Krishna College of Agriculture and Technology (KRISAT), Usilampatti, comprises agricultural lands distributed across several survey numbers with varying soil characteristics and land use patterns. However, systematic information on the fertility status of these soils has not been documented. Therefore, the present investigation was undertaken to evaluate the fertility status of KRISAT farm soils through the assessment of available macro-nutrients, micronutrients, organic carbon, and nutrient index values. The study aims to identify nutrient constraints across different survey numbers and generate baseline information that can support site-specific nutrient management, balanced fertilizer application, sustainable crop production, and future research activities within the institution.

Materials and Methods

The present study was carried out at the instructional farm of Krishna College of Agriculture and Technology (KRISAT), Usilampatti, Tamil Nadu, to assess the fertility status of soils under different survey numbers. A total of 62 geo-referenced surface soil samples (0–15 cm depth) were collected from different survey numbers of the farm using standard soil sampling procedures. The collected soil samples were air-dried under shade, gently crushed using a wooden mallet, and passed through a 2 mm sieve for physico-chemical and fertility analyses. The processed samples were analyzed in the Soil Science Laboratory of KRISAT following standard analytical procedures. Available nitrogen was estimated by the alkaline potassium permanganate method (Subbiah and Asija, 1956) [16], available phosphorus by Olsen's sodium bicarbonate extraction method (Olsen *et al*., 1954), and available potassium by neutral normal ammonium acetate extraction followed by flame photometry (Stanford and English, 1949). Soil organic carbon was determined by the Walkley and Black wet oxidation method (Walkley and Black, 1934) [18]. Available micronutrients (Fe, Mn, Zn and Cu) were extracted using DTPA (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M TEA; pH 7.3) as described by Lindsay and Norvell (1978) and quantified using an Atomic Absorption Spectrophotometer (AAS). The analytical data obtained for all soil samples were interpreted based on the standard soil fertility rating limits prescribed for Indian soils. The nutrient status of each survey number was categorized into low, medium, and high fertility classes for macro- and micronutrients wherever applicable. Nutrient Index Values (NIV) for nitrogen, phosphorus, potassium, iron, manganese, zinc, copper, and organic carbon were computed using the standard formula proposed by Parker *et al*. (1951) [9]: Nutrient Index = [(NL × 1) + (NM × 2) + (NH × 3)] / NT, where *NL*, *NM*, and *NH* represent the number of samples falling under low, medium, and high fertility categories, respectively, and *NT* is the total number of samples analyzed. The calculated nutrient index values were used to evaluate the overall fertility status of the KRISAT farm and to identify nutrient constraints for developing appropriate site-specific nutrient management strategies.

Results and discussion

Available Nitrogen

Available nitrogen content ranged from 50.0 to 71.4 kg ha^{-1} with a mean value of 62.8 kg ha^{-1}, indicating an overall low nitrogen fertility status in the KRISAT farm. The lowest value was recorded in Survey No. 101/5 (50 kg ha^{-1}), while the highest value (71.4 kg ha^{-1}) occurred in Survey No. 103/2. The low nitrogen status may be attributed to poor organic matter content (mean organic carbon 0.28%), continuous cultivation, inadequate organic manure application and nitrogen losses through leaching and volatilization. Similar findings have been reported by Kumar *et al*. (2023) and ICAR (2023) [5], who identified nitrogen depletion as a major constraint in intensively cultivated tropical soils.

Available Phosphorus

Available phosphorus varied from 1.4 to 25.0 kg ha^{-1} with an average of 10.9 kg ha^{-1}, indicating considerable spatial variability among survey numbers. The observed variation is mainly attributed to differences in fertilizer application history, phosphorus fixation and soil properties. Most soils belonged to the low to medium fertility category, suggesting phosphorus as one of the major limiting nutrients. Similar variability has been reported by Singh *et al*. (2022) and FAO (2024) [23].

Available Potassium

Available potassium content in the KRISAT farm soils ranged from 52 to 265 kg ha^{-1}, with a mean value of 115.61 kg ha^{-1}. The lowest potassium content was recorded in Survey No. 134/6 (52 kg ha^{-1}), while the highest value (265 kg ha^{-1}) was observed in Survey No. 107/1A. Most survey numbers exhibited low to medium potassium fertility, indicating considerable spatial variability, which may be attributed to differences in parent material, soil texture, clay mineralogy and fertilizer management. Higher potassium levels in some locations may be associated with localized fertilizer application and weathering of potassium-bearing minerals, whereas lower values may result from continuous crop removal and inadequate nutrient replenishment. Similar observations were reported by Rao *et al*. (2022) and Tiwari *et al*. (2024), who documented declining potassium reserves and marked spatial variability in intensively cultivated Indian soils.

Table 1: Macro, micronutrient and organic carbon content of different soils of KRISAT

Sl.no	Survey no	Macro nutrients (kg/ha)			Micronutrients				Organic carbon (%)
		N	P	K	Fe	Mn	Zn	Cu	
1.	135/6	64	11.3	178	3.85	5.27	0.92	1.27	0.28
2.	131/3	63	25	135	4.18	4.3	0.6	0.48	0.28
3	131/4A	60	20	138	7.15	5.53	0.91	1.23	0.27
4.	131/4B	60	10	135	5.8	5.62	1.17	0.97	0.27
5.	133/2	64	10	150	5.23	3.68	0.96	1.05	0.28
6.	133/1	64	8.8	104	8.05	4.81	1.08	0.89	0.28
7.	134/1	60	8.8	119	4.24	6.29	0.74	1.15	0.27
8.	103/2	71.4	11.3	115	4.98	5.44	0.72	1.28	0.32
9.	133/2	66	8.8	115	5.52	4.4	1.13	0.96	0.29
10.	134/2	63	20	119	7.38	3.46	0.93	0.96	0.28
11.	117/1	65.8	8.8	131	5.96	6.3	0.88	1.5	0.29
12.	117/2	62	20	119	7.46	5.15	0.63	1.85	0.28
13.	117/3	71	12.5	104	5.22	5.7	0.84	1.68	0.32
14.	117/2	63	13.8	96	5.62	4.38	0.84	1.52	0.28
15.	130/6	63	11.3	92	7.71	4.93	0.85	0.73	0.28
16.	131/2	62	8.8	119	7.56	6.18	1.15	1.1	0.28
17.	134/4	63	20	115	6.91	5.17	1.03	0.87	0.28

18.	134/5	64	7.5	142	4.13	5.91	1.08	0.67	0.28
19.	135/4	60	11.3	173	7.98	4.36	0.9	0.49	0.27
20.	134/7	66	11.3	119	8.73	4.43	0.74	1.38	0.29
21.	104/3	64	7.5	155	6.94	3.35	0.83	1.5	0.28
22.	103/1	63	10	159	7.09	5.33	0.78	1.08	0.28
23.	107/1A	57	12.5	265	6.36	6.72	0.9	1.1	0.25
24.	100/7	63	8.8	127	7.12	7.6	0.64	1.22	0.28
25.	101/5	50	6.3	112	5.26	5.72	0.9	1.4	0.22
26.	127/4B	67	13.8	119	5.12	5.06	0.86	1.16	0.30
27.	197/4C1	63	10	155	4.86	5.1	0.72	1.12	0.28
28.	100/1	60	20	104	6.8	6.32	0.96	1.46	0.27
29.	130/6	66	10	100	6.49	5.12	0.48	1.24	0.29
30.	98/4	59	12.5	104	6.4	7.26	0.92	1.24	0.26
31.	135/5	70	8.8	119	4.58	5.32	1.1	1.36	0.31
32.	100/3C	63	16	168	4.38	4.87	0.72	1.67	0.28
33.	60/4A	64	12.5	150	7.64	4.92	0.57	1.46	0.28
34.	100/6	63	25	135	6.56	4.06	0.59	0.93	0.28
35.	100/3A	60	15	142	6.44	3.61	1.05	0.59	0.27
36.	115/2	64	20	131	8.02	4.19	0.65	1.45	0.28
37.	135/1	64	25	115	8.16	2.31	0.87	1.05	0.28
38.	127/4A1	60	8.8	127	7.89	4.57	0.94	1.83	0.27
39.	127/4C2	64	8.8	138	6.95	2.75	1.15	0.75	0.28
40.	127/4A2	59	10	131	6.18	2.96	0.49	1.28	0.26
41.	135/5	60	10	115	7.23	3.82	1.21	0.85	0.27
42.	130/7	60	7.5	104	6.39	3.29	0.8	0.16	0.27
43.	134/1	63	8.8	119	5.07	3.49	0.63	1.43	0.28
44.	130/2	64	4.3	62	2.44	4.63	0.44	1.22	0.28
45.	89/3	60	6.3	87	4.62	2.66	0.64	0.96	0.27
46.	94/2	70	2.9	62	4.68	4.63	0.66	1.62	0.31
47.	95/1	66	4.3	92	2.66	4.63	0.36	1.22	0.29
48.	89/1	60	3.6	87	2.62	2.66	0.44	1.62	0.27
49.	134/6	62	4.33	52	4.62	6.44	0.48	1.62	0.28
50.	122/2	56	8.8	62	3.64	4.66	0.86	1.06	0.25
51.	92/1	57	7.5	92	4.62	4.63	0.97	1.62	0.25
52.	118/4	60	8.8	133	5.44	3.94	0.86	1.29	0.27
53.	118/3	59	1.4	62	4.62	3.94	0.66	1.64	0.26
54.	124/1	60	2.1	52	5.22	4.66	0.76	1.24	0.27
55.	118/5	66	4.3	72	4.66	4.62	0.68	1.63	0.29
56.	60/3B	62	6.3	87	4.26	3.64	0.63	1.04	0.28
57.	122/1	64	2.1	92	4.64	4.62	0.66	1.82	0.28
58.	127/4C3	66	4.3	72	4.69	4.64	0.44	1.44	0.29
59.	118/2	60	5	62	6.29	6.22	0.34	1.92	0.27
60.	92/4B	62	6.3	143	4.2	4.18	0.66	1.29	0.28
61.	118/1	60	7.5	133	3.62	4.62	0.94	1.62	0.27
62.	93/1	59	2.9	52	4.66	4.63	0.93	0.99	0.26

Available Iron (Fe)

Available iron content in the KRISAT farm soils ranged from 2.44 to 8.73 mg kg^{-1}, with a mean value of 5.71 mg kg^{-1}. The lowest concentration was recorded in Survey No. 130/2, while the highest value (8.73 mg kg^{-1}) was observed in Survey No. 134/7. Most soil samples contained iron above the critical deficiency level (4.5 mg kg^{-1}), indicating an overall adequate iron status, although a few survey numbers showed comparatively lower concentrations. The observed variability may be attributed to differences in soil pH, organic carbon, parent material and weathering intensity. Similar findings were reported by Kumar *et al*. (2022) and Singh *et al*. (2023) [13], who observed adequate DTPA-extractable iron in cultivated soils of southern India with only localized deficiencies.

Available Manganese (Mn)

Available manganese content in the KRISAT farm soils ranged from 2.31 to 7.60 mg kg^{-1}, with a mean value of 4.74 mg kg^{-1}. The lowest concentration was recorded in Survey No. 135/1, while the highest value (7.60 mg kg^{-1}) was observed in Survey No. 100/7. Most soil samples contained manganese concentrations above the critical deficiency limit, indicating an overall medium to high manganese fertility status. The adequate manganese availability may be attributed to the nature of the parent material, continuous weathering of manganese-bearing minerals and prevailing soil conditions. The observed spatial variability among survey numbers could be due to differences in soil reaction, drainage, organic matter content and management practices. Similar results were reported by Ramesh *et al*. (2024) [10], who found adequate DTPA-extractable manganese in cultivated soils of Tamil Nadu, while FAO (2024) reported that manganese deficiency is generally localized and occurs mainly in highly calcareous or excessively limed soils.

Available Zinc (Zn)

Available zinc content in the KRISAT farm soils ranged from 0.34 to 1.21 mg kg^{-1}, with a mean value of 0.79 mg kg^{-1}. The lowest zinc concentration was recorded in Survey No. 118/2, whereas the highest value (1.21 mg kg^{-1}) was observed in Survey No. 135/5. Several survey numbers recorded zinc concentrations close to the critical deficiency level, indicating that zinc is one of the major micronutrient constraints in the study area. The relatively low zinc availability may be attributed to low organic carbon content, continuous nutrient removal by crops, alkaline soil conditions and phosphorus-induced zinc fixation. Similar findings have been reported in intensively cultivated soils of India, where zinc deficiency has emerged as the most widespread micronutrient disorder due to imbalanced fertilizer use (ICAR, 2023; Sharma *et al*., 2023) [4].

Available Copper (Cu)

The available copper content of the KRISAT soils ranged from 0.16 to 1.92 mg kg^{-1}, with a mean value of 1.23 mg kg^{-1}. The lowest concentration was recorded in Survey No. 130/7, while the highest value (1.92 mg kg^{-1}) was observed in Survey Nos. 100/7, 130/2 and 95/1. Most of the soil samples contained copper concentrations above the critical deficiency level, indicating an overall adequate copper status despite noticeable spatial variability. The observed variation may be attributed to differences in soil organic matter, texture and management practices, which influence copper availability. Similar findings were reported by Kumar *et al*. (2023) [5], who observed that copper deficiency is relatively uncommon in cultivated soils of southern India due to its strong adsorption by clay minerals and organic matter.

Organic Carbon

Organic carbon content in the KRISAT farm soils ranged from 0.22 to 0.31%, with a mean value of 0.28%, indicating an overall low organic carbon status. The lowest value was recorded in Survey No. 101/5, while the highest values were observed in Survey Nos. 94/2 and 135/5. The low organic carbon content may be attributed to continuous cultivation, inadequate application of organic manures, rapid decomposition of organic residues under tropical climatic conditions and removal of crop residues after harvest. Similar findings have been reported in intensively cultivated soils of southern India (Kumar *et al*., 2023) [5]. Low soil organic carbon adversely affects nutrient mineralization, microbial activity, soil structure and fertilizer use efficiency, and is closely associated with the poor nitrogen status observed in the present study. Enhancing soil organic carbon through integrated nutrient management, including the application of farmyard manure, compost, green manures and crop residue incorporation, is essential for improving soil fertility, nutrient availability and sustainable crop production (Lal, 2023; FAO, 2024) [6].

Nutrient Index Values

The nutrient index values indicated low fertility for nitrogen (1.00), copper (1.00) and organic carbon (1.00), low to medium fertility for phosphorus (1.43) and potassium (1.53), medium fertility for iron (1.96) and zinc (1.98), and high fertility for manganese (2.75). These results suggest that nitrogen remains the major limiting nutrient in the KRISAT farm, followed by deficiencies in organic carbon and copper, whereas manganese is sufficiently available. The nutrient index provides a useful tool for identifying nutrient constraints and developing site-specific nutrient management strategies.

Conclusion

The present investigation revealed considerable spatial variability in the fertility status of soils distributed across different survey numbers of the KRISAT farm. Available nitrogen was uniformly low throughout the study area, while phosphorus and potassium exhibited low to medium fertility status. Among the micronutrients, iron, manganese and zinc were generally sufficient in most survey numbers, although localized deficiencies were observed. Organic carbon content remained uniformly low, indicating poor soil organic matter accumulation and emphasizing the need for organic resource management. The computed nutrient index values identified nitrogen, copper and organic carbon as the principal limiting factors affecting soil fertility, whereas phosphorus, potassium, iron and zinc belonged predominantly to the medium fertility category. Manganese exhibited adequate availability across the farm. These findings indicate that balanced fertilizer application, integrated nutrient management and periodic soil fertility monitoring are essential for sustaining crop productivity and maintaining soil health. The study establishes a valuable baseline database for future soil fertility evaluation and provides scientific information for implementing site-specific nutrient management and Soil Test Crop Response (STCR)-based fertilizer recommendations within the KRISAT farm. Adoption of these strategies will improve fertilizer use efficiency, enhance crop productivity and promote sustainable management of land resources.

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