Nutrient Distribution Patterns in Soil Across Various Locations in Muzaffarnagar and Ghaziabad Districts of Uttar Pradesh Under a Rice-Sugarcane Cropping Sequence

Abstract

A study was conducted to evaluate the macro and micronutrient levels in the soil under the sugarcane-wheat cropping sequence and its relationship with soil characteristics. Understanding the nutrient status is vital for the efficient application of fertilizers, as widespread deficiencies in both macro and micronutrients are being reported in the soils of Uttar Pradesh. The rice-sugarcane cropping sequence is a prominent practice in the northwestern plains of Uttar Pradesh and Uttarakhand, covering 10-11% of the net cultivated area in these regions. Over recent years, sugarcane and wheat yields have plateaued in these areas due to declining factor productivity. Soil samples were collected from depths of 0-15 cm, 15-30 cm, and 30-45 cm at four locations in the Muzaffarnagar and Ghaziabad districts under the rice-sugarcane sequence. The available zinc content in the surface soil (0-15 cm) ranged from 0.605 to 0.883 mg/kg, and in the sub-surface soil (30-45 cm), it varied between 0.111 to 0.629 mg/kg, with an average of 0.083 mg/kg in surface soil and 0.435 mg/kg in sub-surface soil. A correlation analysis between various soil properties across different locations at three soil depths (0-15 cm, 15-30 cm, and 30-45 cm) was also conducted. The findings indicated that the soils are generally low in nitrogen, low to medium in phosphorus and potassium, and sufficiently supplied with copper, iron, manganese, and zinc in the surface layer. Future research on nutrient distribution in these areas will help advance precision agriculture, improve fertilizer management, and boost crop productivity while minimizing environmental harm. This

research will contribute to sustainable soil management, economic benefits for farmers, and provide valuable insights for regional agricultural policies, further supporting food security.

Keywords: macro and micronutrient, cropping sequence, sugarcane

Introduction

"Sugarcane-based cropping systems are widely practiced across India. As a significant cash crop, sugarcane is grown on 4.02 million hectares in the country, with an average yield of 58.98 tons per hectare (Fertilizer Association of India, 2005). Sugarcane has high nutrient requirements, depleting approximately 1.2 kg of nitrogen, 0.22 kg of phosphorus, and 2.83 kg of potassium per ton of cane produced" (Menhi Lal and Singh, 2002). "In the northwestern plains of Uttar Pradesh and Uttarakhand, the rice-sugarcane cropping sequence is one of the most common systems, accounting for 10-11% of the total cultivated area. Over the years, sugarcane and wheat yields have stagnated in these areas, primarily due to a decline in factor productivity" (Yadav et al., 1998). "The study found that the soils in the area were sandy loam in texture, slightly alkaline, and non-saline in nature. In terms of nutrient status, available nitrogen was low in both surface (0-15 cm) and subsurface (15-30 cm) soils, while phosphorus and potassium levels ranged from low to medium at both depths. Additionally, nutrient availability decreased progressively with increasing soil depth" (Kumar Vipin et al., 2021). "The primary reason for this decline in productivity has been attributed to the loss of organic matter. Some studies suggest that pH is negatively correlated with available nitrogen, phosphorus, and potassium in surface (0-15 cm) and subsurface (15-30 cm) soils" (Kumar Vipin et al., 2024). "Soil organic matter plays a critical role in nearly all aspects of soil health related to crop production. Macronutrients (N, P, and K) and micronutrients (Cu, Fe, Mn, and Zn) are vital elements that determine soil fertility, which is a key factor influencing crop yields. Evaluating soil fertility in relation to its characteristics is crucial for sustainable crop production. Integrated nutrient management, incorporating organic and inorganic sources, biofertilizers, and green manuring, holds significant potential for maintaining soil fertility and crop yields in sugarcane-based systems" (Yadav and Shukla, 2016). "Due to the imbalance and inadequate use of fertilizers, the efficiency of chemical fertilizers has dramatically decreased in intensive cropping systems in recent years" (Chandra et al., 2008). The stagnation in crop productivity cannot be overcome without the careful use of macro and micronutrients. Therefore, an assessment of these nutrients in soils under the sugarcane-wheat cropping sequence, along with their interaction with soil characteristics, is essential, especially since widespread deficiencies in these nutrients are being observed in the soils of Uttar Pradesh.

Materials and method:

Soil samples were collected from depths of 0-15, 15-30, and 30-45 cm at four different locations in the Muzaffarnagar and Ghaziabad districts, under the rice-sugarcane cropping sequence. These samples were air-dried in the shade, gently crushed using a wooden roller, and passed through a 2.0 mm sieve to obtain uniform representative samples. The processed soil samples were then analyzed for their physico-chemical properties following standard procedures. The analyses included pH and electrical conductivity (using a 1:2 soil-water suspension), organic matter content (Walkley and Black, 1934), available nitrogen (Subbiah and Asija, 1956), available phosphorus, and available potassium (Jackson, 1973). The available micronutrient cations (Mn, Zn, Fe, Cu) were extracted using DTPA (Diethylene triamine pentaacetic acid) extractant. All analytical work was conducted in the laboratory of the Department of Soil Science at SVPUA&T, Meerut, Uttar Pradesh, India. The samples were collected from the Purkazi, Baghra, Shahpur, and Khatauli blocks in Muzaffarnagar district, as well as from the Loni, Bhojpur, and Rajapur blocks in Ghaziabad district.

Result and discussion

Chemical properties

The soil pH across various depths generally ranged from normal to alkaline (Table-1). Specifically, surface soil (0-15 cm) had a pH of 8.1 to 8.8, while subsurface layers at 15-30 cm and 30-45 cm showed a pH between 8.0 and 8.8. The electrical conductivity (EC) of surface soil varied from 0.189 to 0.428 dSm^{-1}, with subsurface soil ranging between 0.170 to 0.223 dSm^{-1}. The average EC values were 0.172 dSm^{-1} for surface soil and 0.216 dSm^{-1} for subsurface soil. Cation exchange capacity (CEC) in surface soil (0-15 cm) ranged from 10.13 to 14.82 $cmol(p^{+})kg^{-1}$, while in subsurface soil (30-45 cm), it varied from 7.43 to 13.47 $cmol(p^{+})kg^{-1}$, with average values of 9.69 and 17.47 $cmol(p^{+})kg^{-1}$, respectively. Organic carbon content was higher at the surface but decreased with depth. It ranged from 6.6 to 7.9 g kg^{-1} in surface soil (0-15 cm) and from 1.4 to 4.6 g kg^{-1} in subsurface soil (30-45 cm), with average values of 1.8 g kg^{-1} and 3.6 g kg^{-1}, respectively.

Nutrients status and soil fertility

Soil fertility indicates the nutrient status and availability in different soils essential for plant growth. The available nitrogen content in the surface layer (0-15 cm) ranged from 93.72 to 127.11 kg ha^{-1}, while in the subsurface layer (30-45 cm), it varied between 63.09 and 83.98 kg ha^{-1}. The average values were 38.44 kg ha^{-1} for surface soil and 74.73 kg ha^{-1} for subsurface soil (Table-1), highlighting that all soils were low in available nitrogen. Nitrogen content was highest at the surface and decreased with increasing depth. This reduction is mainly due to the declining organic carbon content with depth and the regular depletion of nitrogen in surface soil, where crop cultivation is concentrated and nitrogen is replenished through external sources during farming (Prasuna Rani et al., 1992).

The available phosphorus levels in surface soil (0-15 cm) ranged from 4.12 to 12.53 kg ha^{-1}, with an average of 1.31 kg ha^{-1}, while in the subsurface soil (30-45 cm), the range was from 2.65 to 8.38 kg ha^{-1}, averaging 5.82 kg ha^{-1}. The highest phosphorus concentrations were found in the surface soil, which decreased with depth. This trend may be due to the concentration of crop cultivation within the rhizosphere and the replenishment of phosphorus through external sources. The lower phosphorus content in the subsurface soil could be attributed to the fixation of released phosphorus by clay minerals (Leelavathi et al., 2009).

The available potassium in the surface soil (0-15 cm) ranged from 126.71 to 664.20 kg ha^{-1}, while in the sub-surface soil (30-45 cm), it varied between 100.23 and 609.60 kg ha^{-1}, with average values of 90.04 and 589.05 kg ha^{-1}, respectively. Potassium levels were higher in the surface soil and decreased with increasing soil depth.

Micronutrients

The DTPA-extractable copper ranged from 0.65 to 1.75 mg kg^{-1} in the surface soil (0-15 cm) and from 0.47 to 1.44 mg kg^{-1} in the sub-surface soil (30-45 cm), with average values of 0.17 mg kg^{-1} for the surface soil and 0.93 mg kg^{-1} for the sub-surface soil. All measured values exceeded the critical limit of 0.20 mg kg^{-1} established by **Lindsay and Norvell** (1998).

The DTPA-extractable iron levels ranged from 2.69 to 7.03 mg kg^{-1} in the surface soil (0-15 cm) and from 2.15 to 5.35 mg kg^{-1} in the sub-surface soil (30-45 cm), with average values of 1.95 mg kg^{-1} for the surface soil and 4.58 mg kg^{-1} for the sub-surface soil. According to the critical limit of 4.5 mg kg^{-1} proposed by Lindsay and Norvell (1978), all surface soil samples (0-15 cm), except for the Khandawali (M) site, were deemed sufficient in available iron. A decreasing trend in iron concentration with increasing depth was observed across all four locations.

The DTPA-extractable manganese ranged from 1.80 to 5.10 mg kg^{-1} in the surface soil (0-15 cm) and from 1.64 to 4.51 mg kg^{-1} in the sub-surface soil (30-45 cm), with average values of 1.51 mg kg^{-1} for the surface soil and 3.35 mg kg^{-1} for the sub-surface soil. According to the critical limit of 1.0 mg kg^{-1} established by Lindsay and Norvell (1978), all the soils were found to be sufficient in available manganese.

Available zinc levels ranged from 0.605 to 0.883 mg kg^{-1} in the surface soil (0-15 cm) and from 0.111 to 0.629 mg kg^{-1} in the sub-surface soil (30-45 cm), with average values of 0.083 mg kg^{-1} for the surface soil and 0.435 mg kg^{-1} for the sub-surface soil. According to the critical limit of 0.6 mg kg^{-1} set by Lindsay and Norvell (1978), all surface soils, except for the Khandawli (M) site, were considered sufficient in available zinc.

Correlation study

Correlation coefficients among various soil properties in rice-sugarcane cropping sequences from different locations in Muzaffarnagar and Ghaziabad districts were analyzed at three soil depths: 0-15 cm, 15-30 cm, and 30-45 cm. The results indicated that organic carbon was highly positively correlated with available nitrogen (r = 0.876**), total nitrogen (r = 0.725**), microbial biomass carbon (r = 0.752**), copper (r = 0.651**), and zinc (r = 0.865**). It also showed a positive correlation with available phosphorus (r = 0.747*), iron (r = 0.768*), and manganese (r = 0.615*). In contrast, organic carbon had a negative correlation with cation exchange capacity (CEC) (r = -0.010), available potassium (r = 0.322), and bulk density (r = -0.578).

Soil pH exhibited a negative correlation with iron (r = -0.385) and zinc (r = -0.147), while showing a significant positive correlation with manganese (r = -0.071*). It also had a positive correlation with copper (r = 0.258). The cation exchange capacity (CEC) was negatively correlated with sand (r = -0.668) and silt (r = -0.623), and had a highly significant negative correlation with clay (r = -0.235**). Additionally, available soil nitrogen was significantly and positively correlated with total nitrogen (r = 0.556*) and microbial biomass carbon (r = 0.752*).

Table-1: Physico-chemical properties of soil under rice – sugarcane cropping sequence Muzaffarnagar and Ghaziabad district

Locations	Depth (cm)	pH	EC	CEC	O.C. g/kg	Available macronutrients(kgha^{-1})			Available micronutrients (mgkg^{-1})			
						N	P	K	Cu	Fe	Mn	Zn
Jansath (M)	0-15	8.4	0.201	14.82	7.9	114.96	12.53	664.20	1.75	2.69	2.94	0.645
	15-30	8.8	0.185	12.00	4.1	83.98	8.38	609.60	1.44	2.64	2.23	0.551
	30-45	8.8	0.210	12.47	2.6	74.73	3.38	589.05	0.50	2.15	1.98	0.083

Morna (M)	0-15	8.2	0.189	10.13	6.6	93.72	4.12	126.71	0.87	3.34	1.80	0.765
	15-30	8.4	0.170	7.43	2.4	63.09	2.65	100.23	0.47	2.15	1.64	0.271
	30-45	8.4	0.186	10.80	1.8	38.44	1.31	90.04	0.36	1.95	1.51	0.084
Bhojpur (G)	0-15	7.5	0.303	10.78	6.7	127.11	5.33	243.77	0.65	7.03	5.10	0.605
	15-30	7.6	0.223	13.47	4.2	80.53	3.99	244.67	0.46	5.35	4.51	0.111
	30-45	7.9	0.172	9.69	3.5	71.46	2.07	207.67	0.17	4.58	3.35	0.100
Muradnagar (G)	0-15	8.1	0.428	14.21	6.6	99.65	10.70	185.21	1.56	4.84	4.61	0.883
	15-30	8.0	0.192	12.08	4.6	71.93	6.55	101.04	1.02	4.10	3.06	0.629
	30-45	8.0	0.216	17.47	3.6	60.46	5.82	125.98	0.93	3.30	2.66	0.435
Mean	0-15	-	0.195	12.48	7.2	106.35	8.20	260.34	1.20	5.65	3.45	0.725
	15-30	-	0.185	10.42	3.8	74.30	5.40	280.63	0.88	3.54	2.74	0.420
	30-45	-	0.192	12.30	2.8	58.24	2.80	235.20	0.48	2.50	2.85	0.156

In parentheses M denotes Muzaffarnagar and G for Ghaziabad.

Conclusion:

The analysis of soil samples from Muzaffarnagar and Ghaziabad districts indicated that the soils are typically normal to moderately alkaline and have organic carbon levels ranging from low to medium. Nutrient-wise, the soils are generally low in available nitrogen, low to medium in available phosphorus and potassium, and sufficiently endowed with available copper, iron, manganese, and zinc in the surface layers.

Practically, this study enhances fertilizer use efficiency by providing insights into nutrient distribution, leading to higher crop yields and reduced costs. It promotes sustainable agriculture by preventing over-application of fertilizers and reducing environmental impact. Furthermore, the research supports the development of targeted agricultural policies and improves farm management practices.

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Reference:

Kumar Vipin, Kumar Satendra, Singh Akansha, Dhyani B.P., Shahi U.P., Kumar Mukesh, Purushottum, Navsare R.I. (2024) Depth wise variability of available N, P and Kat different location under rice-pea-sugarcane cropping system in Meerut district (U.P.). Indian Journal of Agriculture Research. Volume 58 issue: 3: 501-506.

Kumar, Vipin., Kumar Satendra., Singh Akansha, Shahi, U.P. (2021) Availability of N, P, K and Their Relationship between Organic Carbon under Sugarcane-Ratoon-Wheat Cropping System in Western Uttar Pradesh Provinces, India. International journal of plant and soil science.

Anuj Kumar, Kamlesh Kumar Yadav, Virendra Singh, Uma Shankar Tiwari, Dinesh Kumar and Pankaj Kumar Singh (2022) Effect of Integrated Nutrient Management on Soil Fertility and Soil Microbial Population after Cropping to Wheat Crop in Western Uttar Pradesh. International Journal of Plant & Soil Science 34(19): 117-125.

Chandra, R., Rana, N.S., Kumar, S. and Panwar, G.S. (2008). Effect of sugarcane, residue and green manure practices in sugarcane- ratoon – wheat sequence on productivity, soil fertility and soil biological properties. *Archives of Agronomy and Soil Science* 54 (6) 651 - 664

Fertilizer Association of India (FAI). 2005. Fertilizer Statistics 2004-2005. *New Delhi: FAI.*

Lal, Menhi and Singh, A.K. (2002) Importance of plant nutrient in sugarcane. *Fertilizer News 47* (11): 91-98.

Leelavathi, G.P. Naidu, M.V.S., Ramavatharram, N. and Karuna Sagar, G. (2009) Studies of genesis, classification and evaluation of soil for sustainable land use planning in Yerpedu Mandal of Chittoor District, Andhra Pradesh. *J. Indian society of soil science* 57 (2) 109-120.

Lindsay, W.L. and Norvell, W.A. (1978) Development of DTPA soil test for zinc, iron, manganese and coper. *Soil Science Society of America Journa*l 42, 421-428.

Rani, Prasuna, Pillai, R.N., Prasad, Bhanu and Subbaiah, G.V. (1992) Nutrient status of some red and associated soil of Nellore district under Somasila Project in *Andhra Agriculture Journal* 39, 1-5.

Yadav, R.L., Yadav, D.S., Singh, R.M. and Kumar, A. (1998). Long term effect of inorganic fertilizer inputs and crop productivity in rice wheat cropping system. *Nutrient Cycling in Agro Ecosystem* 51:193 – 200.