Environment and Ecology 43 (4A) : 1181—1186, October—December 2025
Article DOI: https://doi.org/10.60151/envec/HDMI7698
ISSN: 0970-0420 (Print), ISSN: 3049-3625 (Online)

Evaluation of Available Sulfur and DTPA Extractable Micronutrients in Rice Growing Area of Banda District of Bundelkhand Region of Uttar Pradesh, India

Suraj Mishra, Anand Kumar Chaubey, Jagannath Pathak, G. S. Panwar, Umesh Chandra

Received 11 October 2025, Accepted 2 December 2025, Published on 23 December 2025

ABSTRACT

An experiment was conducted in the rice growing area of Badokhar Khurd block, Banda district, in the Bundelkhand region to evaluate available Sulfur and DTPA extractable micronutrients. A total of 300 geospatial soil samples were randomly collected from the surface (0-15 cm) based on land variability. The collected samples were analyzed for available sulfur and cationic micronutrients (Mn, Cu, Zn, and Fe). The data showed that among the total samples 21% were low, 72% were medium and 7% were high in available sulfur. Regarding micronutrients, most samples were low in available zinc (76.7%) and high in available manganese (73.3%), copper (100%) and iron (76.7%). Based on the Nutrient Index Value (NIV), the soils of the study area were found to be in low fertility for available zinc (1.23), medium for available sulfur (1.86) and high for available manganese (2.73), copper (3) and iron (2.76). It is expected that this study will help guide practices for sustainable soil fertility management and aid in developing future agricultural research strategies in the farm.

Keywords Soil fertility, Micronutrients, Nutrient index, Soil properties, Soil testing.

Suraj Mishra[1]*, Anand Kumar Chaubey[2], Jagannath Pathak[3], G. S. Panwar[4], Umesh Chandra[5]

[2,3]Professor

[1,2,3]Department of Soil Science and Agricultural Chemistry, Banda University of Agriculture and Technology (BUAT), Banda, Uttar Pradesh 210001, India

[4]Professor, Department of Agronomy, Banda University of Agriculture and Technology (BUAT), Banda, Uttar Pradesh 210001, India

[5]Assistant Professor, Department of Statistics and Computer Science, Banda University of Agriculture and Technology (BUAT), Banda, Uttar Pradesh 210001, India

Email: surajmishras306@gmail.com
*Corresponding author

INTRODUCTION

The rice-wheat system is the main farming system in India, accounting for over 75% of the country's total food grain production (Chaubey *et al.* 2023). Rice is the primary staple food crop and covers nearly 90% of the total cultivable area during the summer (*kharif)* season (Athokpam *et al.* 2013). It plays a crucial role in South Asia, where it takes up about 45% of the total cultivated land and significantly contributes to national economies and rural livelihoods (IRRI 2019). In Asia, more than two billion people get 60-70% of their energy needs from rice and its derived products

(Ahmed and Yusuf 2020). Globally, India ranks as the second-largest rice producer and consumer, especially in the eastern regions (Chaudhary *et al.* 2025). From 1990, when rice production was 598.67 million tonnes, to 2020, with 756.74 million tonnes, the use of high-yielding rice varieties, nutrient and soil management, improved water use efficiency, and effective pest and weed management has increased global rice yields by 26.4% (FAOSTAT 2023, Sadhukhan *et al.* 2023).

Soil is a limited natural resource and its management and health directly influence the sustainability of the agro-ecosystem and human well-being. It is one of the most vital natural resources in a country, used to develop optimal land use plans and maximize agricultural output. Soils vary greatly in their morphological, physical, chemical, mineralogical and biological characteristics. Because these traits determine how soil responds to management practices, it is essential to have information about these characteristics for each soil. The sustainable productivity of soil mainly depends on its ability to supply essential nutrients to growing plants.

In India, the main challenge in soil fertility management is to stabilize the necessary nutrient levels for the selected crop based on factors like soil type, crop varieties or hybrids, season and others. Soil fertility varies throughout the growing season each year due to changes in the amount and availability of mineral nutrients caused by the addition of fertilizers, manure, compost, mulch, lime or sulfur, along with leaching. Therefore, soil testing is essential to determine the current fertility status and provide information on plant nutrient availability and the appropriate fertilizer application rates for specific crops to maximize yields. Micronutrient deficiency has become a significant constraint to soil productivity, stability and sustainability (Kumar and Babel 2011). The availability of micronutrients in soils is mainly influenced by parent material, soil pH, soil organic carbon (SOC) and human activities (Shukla *et al.* 2018). These nutrients are also crucial for various plant processes, including enzyme activity and redox reactions (Welch and Graham 2004). In humid regions, micronutrients such as Fe and manganese (Mn) become more available, sometimes to the detriment of plant growth. Conversely, in dry regions, micronutrient availability, including Fe and zinc (Zn), decreases due to the formation of insoluble compounds (Foroughifar *et al.* 2013). Widespread micronutrient deficiencies have been reported in agricultural soils worldwide (Alloway 2008). Such deficiencies of Zn, Fe, Cu, and Mn have also been noted in soils across different regions of India, including the Deccan Plateau Region (Shukla *et al.* 2016, Shukla *et al.* 2018). Therefore, site-specific and balanced management through varying nutrient application rates is key to sustainable agricultural production. The distribution of micronutrients can vary geographically and temporally within management units. In Indian soils, spatial variability in micronutrient availability is considered high due to small farms and diverse management practices (Shukla *et al.* 2016). Soil nutrient depletion adversely affects soil quality, reduces crop yields, threatens food security and sustainable agriculture (Rehman *et al.* 2022, Pathak *et al.* 2025). Thus, characterizing soils and assessing their nutrient supply capacity are vital for ensuring and improving agricultural sustainability. Proper nutrient management is crucial for meeting the needs of a growing global population without harming the environment or human health. Methods such as the nutrient index value and fertility indicators can be used to evaluate soil fertility status (Sahu *et al.* 2023). Consequently, an observational study was conducted to assess available sulfur and DTPA-extractable micronutrients in rice-growing areas of Badokhar Khurd block, Banda district, in the Bundelkhand region of central India.

MATERIALS AND METHODS

Selection of site

Geographically, the study area is located at 25°28'10” N latitudes, 80°21'15" E longitudes to 25°22'08" N latitudes, 80°22'48" E longitudes. The climate of this region is typically Arid to Semi-arid. The rainfall is seasonal, erratic and not properly distributed in this district. The average annual rainfall of the district is 902 mm, of which more than 80% occurs in southwest monsoon. Keeping this view of rice-growing area, Badokhar Khurd block has been selected for the study area. Generally, the soils of Banda district are divided into red and black soils. Further, the red

Table 1. Rating chart of nutrient Iidex value.

Sl. No.	Category	Value	Interpretation
1	Low	<1.67	Low fertility status of the area
2	Medium	1.67-2.33	Medium fertility status of the area
3	High	>2.33	High fertility status of the area

soils are locally divided into Rakar, Parua and black soils are Kabar, Mar, respectively. The total study area covers about 7565.38 ha.

Collection of analysis of soil samples

The soil samples were collected from depths of 0-15 cm based on the topography, soil type, and slope. A total of 300 geo-located soil samples were collected in October and November 2023 after the rice crop harvest. The samples were collected at an interval of approximately 500 m distance. Each soil sample taken was a composite of 8-10 sub-samples from nearby locations, the total volume of the soil samples was thoroughly mixed and reduced to 500 g by quartering technique and shifted to the laboratory for processing. The shifted soil samples were air-dried, processed, and analyzed according to standard procedures described by the following methods: Available sulfur was determined by using 0.15% calcium chloride method (Williams and Steinberg 1959). The available micronutrients (Mn, Cu, Zn and Fe) were determined by using DTPA method (Lindsay and Norvell 1978)

Nutrient index

Nutrient index was interpreted according to the standard formula proposed by Parker *et al.* (1951), modified by Ramamoorthy and Bajaj (1969), which is presented in Table 1. Nutrient index was calculated as per the following formula

Nutrient Index Value (N.I.V) = (Nl × 1 + Nm × 2 + Nh × 3) /NT

Where,

N_l : Indicates number of samples falling in low class of nutrient status

N_m : Indicates number of samples falling in medium class of nutrient status

N_h : Indicates number of samples falling in high class of nutrient status

N_T : Indicates total number of samples analyzed in the given area.

RESULTS AND DISCUSSION

Distribution of available sulfur and cationic micronutrients in rice growing area of Banda is presented in Table 2.

Available sulfur

Sulfur is an essential nutrient for plant growth due to its presence in proteins, glutathione, phytochelatins, thioredoxins, chloroplast membrane lipids, and certain coenzymes and vitamins (Khadka *et al.* 2017). The study area was shown in medium status of available sulfur. With regard to percentage category out of total soil samples, about 21% samples were low, 72% samples were medium and 7% soil samples were high in category. The result indicated that the soil of this zone was sufficient in sulfur. It might be due to the continuous use of single super phosphate (SSP, Sulfur-containing fertilizer) as a source of P and/or sulfur-containing minerals in the soil (Prasad *et al.* 2020).

DTPA extractable micronutrients:

Available manganese

Manganese is the tenth-most abundant element on

Table 2. Distribution of soil parameters with soil fertility rating of rice growing area of Banda.

Sl. No.	Soil parameters	% of sample category			NIV	Fertility rating
		Low	Medium	High		
1	Available sulfur (mg kg^{-1})	21	72	7	1.86	Medium
2	Available manganese (mg kg^{-1})	-	26.7	73.3	2.73	High
3	Available copper (mg kg^{-1})	-	-	100	3	High
4	Available zinc (mg kg^{-1})	76.7	23.3	-	1.23	Low
5	Available iron (mg kg^{-1})	-	23.3	76.7	2.76	High

the surface of the earth. It is involved in many biochemical functions, primarily acting as an activator of enzymes such as dehydrogenases, transferases, hydroxylases, and decarboxylases involved in respiration, amino acid and lignin synthesis, and hormone concentrations (Khadka *et al.* 2017). The DTPA-extractable available manganese in the soils of the studied area was found to be in a high status. As per the percentage category out of total soil samples, about 26.7% samples were medium and 73.3% soil samples were high in category. Similar trends in results were reported by Mishra *et al.* (2023). The higher Mn status in the soils may be attributed to the lower oxidation under optimum soil reaction of the soils and also due to the release of chelated Mn from the organic compounds (Rajamani *et al.* 2020).

Available copper

The DTPA extractable available copper in soils of studied area was shown in high status. Out of total soil samples, all the samples (100%) were high in category. Similar trends in results were reported by Meher *et al.* (2020). Being high status of available copper in the soil, care should be taken during fungicide, pesticide herbicide application in the field because this chemical already contains copper (Rajamani *et al.* 2020).

Available zinc

Zinc plays very important role in plant metabolism by influencing the activities of hydrogenase and carbonic anhydrase, stabilization of ribosomal fractions and synthesis of cytochrome (Khadka *et al.* 2017). The result indicated that the soils of study area were deficient in available zinc. As per percentage category, the majority samples (76.7%) were low and 23.3% soil samples were medium in category. Similar trends in results were reported by Meher *et al.* (2020). Therefore, different organic and inorganic sources of zinc should be applied in the field regularly to reduce zinc deficiency stress for growing crops (Ramulu and Reddy 2018).

Available iron

Iron is an essential nutrient for plants and it plays an important role in the electron transport chains associated with photosynthesis and respiration. The result indicated that the soils of studied area were high status. As per percentage category, the majority samples (76.7%) were high and 23.3% samples were medium in category. Similar trends in results were reported by Mishra *et al.* (2023).

The variations observed in available micronutrients among different soils might be the result of the variable intensity of different pedogenic processes taking place during soil development. The proper nutrient management practice should be adopted especially for those nutrients that are low and high in status, because crops may suffer from their stress. For crop plants in the deficient, sufficient and high fertility area of a particular nutrient 25% more than recommended, exact recommended and 25% less than recommended dose of fertilizer respectively should be provided (Meher *et al.* 2020). The availability of micronutrients in a soil is governed by several factors such as soil pH, EC, organic matter content, micronutrient status of soils, clay content of the soil, soil microbial activities, use of trace element-containing fertilizers, status of macro, and other micronutrient content of the soil (Prasad *et al.* 2020).

Nutrient index studies of sulfur and micro/trace nutrients

The nutrient index value (NIV) was calculated for all soil attributes, based on the rating chart suggested by Ramamoorthy and Bajaj (1969) (Table 1). NI values were interpreted into three categories: Low, medium, and high. The NIV showed in Fig. 1 for available manganese (2.73), copper (3) and iron (2.76) fell into high category. In contrast, available sulfur (1.86) was

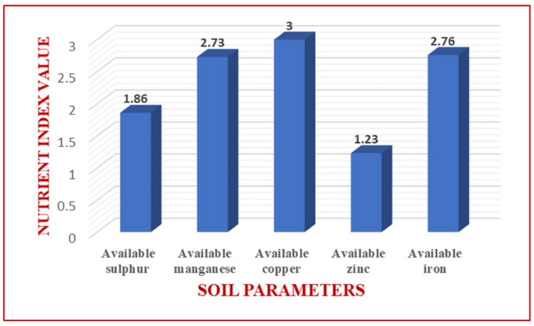

Fig. 1. Nutrient index value of soil parameters.

classified as medium, indicating sufficient fertility. Meanwhile, the nutrient index value of available zinc (1.23) fell into low category, indicating deficient fertility. High NIV of available manganese, copper and iron in Badokhar Khurd block of Banda district in Bundelkhand region have also been confirmed by Khan *et al.* (2017). Similarly, Mishra *et al.* (2023) reported the NIV of available zinc (low) and iron and manganese are high in Mahoba district of Bundelkhand region.

CONCLUSION

The study revealed that the available sulfur was low to high, having 72% in the medium category. Available Zn was low to medium and available Mn and Fe were medium to high. In contracts of availability, Fe was high in category. Soil fertility attributes indicated that soils are low in available zinc, medium in available sulfur and high in available manganese, copper and iron. Overall, the soil fertility level of the study area was high except available sulfur and zinc. Therefore, the area needs to be emphasized on site-specific nutrient management, use of organics as nutrient sources and appropriate agronomic practices to improve the fertility status.

ACKNOWLEDGMENT

The author is greatly thankful to Banda University of Agriculture and Technology, Banda for providing the necessary facilities for the research work.

REFERENCES

Ahmed, M. M., & Yusuf, M. A. (2020). Soil fertility assessment for rice cultivation in Sabuwa Area, Katsina State, Nigeria. *African Journal of Earth and Environmental Science,* 2(2).

Alloway, B. J. (ed). (2008). Micronutrient deficiencies in global crop production. Springer Science & Business Media.

Athokpam, H., Wani, S. H., Kamei, D., Athokpam, H. S., Nong maithem, J., Kumar, D., & Devi, L. (2013). Soil macro-and micro-nutrient status of Senapati district, Manipur (India). *African Journal of Agricultural Research,* 8(39), 4932-4936.

Chaubey, A. K., Mishra, S., Singh, S. K., Chaubey, C., & Pandey, K. P. (2023). Integrated nutrients management for future production: A review. *International Journal of Environment and Climate Change,* 13(11), 1770-1779.

Chaudhary, A., Mishra, A. K., Venkatramanan, V., & Sharma, S. (2025). Enhancing yield and GHG mitigation through site-specific nutrient management for transplanted and direct-seeded rice in Odisha, India. *Frontiers in Sustainable Food Systems,* 9, 1571263.

FAOSTAT. United Nations Food and Agricultural Organization [WWW Document]. Available online: http://www.fao.org/faostat/en/#data (accessed on 14 February 2023).

Foroughifar, H., Jafarzadeh, A. A., Torabi, H., Pakpour, A., & Miransari, M. (2013). Using geostatistics and geographic information system techniques to characterize spatial variability of soil properties, including micronutrients. *Communications in Soil Science and Plant Analysis,* 44(8), 1273-1281.

IRRI. (2019). IRRI annual report 2019. Available online at: http://books.irri.org/AR2019_content.pdf (Accessed October 12, 2023).

Khadka, D., Lamichhane, S., Shrestha, S. R., & Pant, B. B. (2017). Evaluation of soil fertility status of regional agricultural research station, Tarahara, Sunsari, Nepal. *Eurasian Journal of Soil Science,* 6(4), 295-306.

Khan, M. H., Kumar, S., & Mehra, A. K. B.(2017). Remote sensing and GIS based analysis of land use land cover and soil fertility status at inter-block level in Banda district of Uttar Pradesh. *IJCS,* 5(6), 73-80.

Kumar, M., & Babel, A. L. (2011). Available micronutrient status and their relationship with soil properties of Jhunjhunu Tehsil, District Jhunjhunu, Rajasthan, India. *Journal of Agricultural Science,* 3(2), 97.

Lindsay, W. L., & Norvell, W. A. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of America Journal,* 42(3): 421 – 428.

Meher, S. K., Singh, V., Bala, J., Samuel, S., Motghare, R., & Tedia, K. (2020). Assessment of spatial variability of soil fertility status in KVK farm of Pahanda in Durg district, Chhattisgarh using GIS-GPS. *International Journal of Chemical Studies,* 8(2), 304-309.

Mishra, S., Kumar, D., Gupta, A. K., & Kumar, S. (2023). Soil fertility status of KVK and RARS Belatal of Mahoba district under Bundelkhand region of UP. *Journal of Soil and Water Conservation*, 22(4), 427-432.

Parker, F. W., Nelson, W. L., Winters, E., & Miles, I. E. (1951). The broad interpretation and application of soil test information. *Agronomy Journal,* 43(3), 105-112.

Pathak, A., Marahatta, S., & Bhatta, S. (2025). Assessment of Site-Specific Nutrient Management on Growth and Yield of Rice (*Oryza sativa* L. indica). *Turkish Journal of Agriculture-Food Science and Technology,* 13(8), 2003-2011.

Prasad, M., Mahawer, S. K., Govindasami, P., & Kumar, S. (2020). Assessment of Soil Fertility Attributes in Selected Districts of Bundelkhand Region of Central India. *Current Journal of Applied Science and Technology,* 39(48), 326-334.

Rajamani, K., Hari, N., & Rajashekar, M. (2020). Soil Fertility Evaluation and GPS-GIS Based Soil Nutrient Mapping of Krishi Vigyan Kendra, Palem, Telangana. *International Research Journal of Pure and Applied Chemistry*, 21(23), 139-145.

Ramamoorthy, B., & Bajaj, J. C. (1969). Available nitrogen, phosphorus and potassium status of Indian soils. *Fertilizer News,* 14:25-36.

Ramulu, C. H., & Reddy, P. R. R. (2018). Soil fertility status of regional agricultural research station, Warangal

(Telangana). *Journal of Pharmacognosy and Phytochemistry,* 7(6), 1852-1856.

Rehman, A., Farooq, M., Lee, D. J., & Siddique, K. H. (2022). Sustainable agricultural practices for food security and ecosystem services. *Environmental Science and Pollution Research,* 29(56), 84076-84095.

Sadhukhan, R., Kumar, D., Sen, S., Sepat, S., Ghosh, A., Shivay, Y. S., & Hossain, A. (2023). Precision nutrient management in zero-till direct-seeded rice influences the productivity, profitability, nutrient, and water use efficiency as well as the environmental footprint in the indo gangetic plain of India. *Agriculture*, 13(4), 784.

Sahu, D., Srivastava, L.K., Porte, S. S., Jatav, G. K., & Baghel, S. (2023). Evaluation of Soil Fertility Status of Research Farm, College of Agriculture and Research Station, Katghora, Korba, Chhattisgarh. *International Journal of Environment and Climate Chang*e, 13(10), 2468-2473.

Shukla, A. K., Behera, S. K., Lenka, N. K., Tiwari, P. K., Prakash, C., Malik, R. S.,& Chaudhary, S. K. (2016). Spatial variability of soil micronutrients in the intensively cultivated Trans-Gangetic Plains of India. *Soil and Tillage Research,* 163, 282–289.

Shukla, A. K., Sinha, N. K., Tiwari, P. K., Prakash, C., Behera, S. K., Surendra Babu, P., & Patra, A. K. (2018). Evaluation of spatial distribution and regional zone delineation for micronutrients in a semiarid Deccan Plateau Region of India. *Land Degradation & Development,* 29(8), 2449-2459.

Welch, R. M., & Graham, R. D. (2004). Breeding for micronutrients in staple food crops from a human nutrition perspective. *Journal of Experimental Botany,* 55, 353–364.

William, C. H., & Steinberg, A. (1959). Soil sulfur fractions as chemical indices of available Sulfur in Australian soils. *Australian Journal of Agriculture Research,* 10(3), 340-352. https://doi.org/10.1071/AR9590340