

# Spatial variability of soil nutrients using Nutrient Index Value Approach in KVK, Jalaun, Uttar Pradesh

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## ABSTRACT

A study was conducted in 2023-24 to evaluate the soil fertility status of KVK Farm using nutrient index values of various soil characteristics. Total 108 georeferenced soil samples were collected from KVK Farm, Jalaun. Soil samples were analysed using standard procedure. The estimated values of soil characteristics were categorized as low, medium and high. These estimated values are used to assess the nutrient index ranking. The Nutrient index value (NIV) for organic carbon (1.42), available nitrogen (1.06), available zinc (1.43) and exchangeable Calcium & Magnesium (1.05) were found in the low categories and showed poor fertility status, whereas nutrient index values of available phosphorus (2.04), available sulphur (2.01), available copper (2.0), available boron (1.79), available manganese (2.12) and available iron (1.94) were found in medium categories, showing good fertility status and available potassium (2.48) were found in the high categories and ranked in high fertility status of respective nutrients in the study area. Achieving optimum crop production and soil fertility in the study area requires a proper rating of nutrients present in soil and their management options for higher yield potential.

**Keywords:** Nutrient index, Soil fertility, Nutrient, Soil properties, Remote sensing

## INTRODUCTION

Agriculture is a very important sector for the sustained growth of the Indian economy. Soil plays a major role in determining the sustainable productivity of an agro ecosystem. Soil is the basic natural resource for crop production and it supplies essential nutrients for plant growth, food security, necessary components of human and animal food and the nutritional security of the country. According to an FAO analysis generally 95% of food products originated directly or indirectly from the soil. Soil-ecological relationships supporting sustainable nutrient delivery, which emphasizes the central role of soil biological activity in maintaining crop productivity (Bhardwaj *et al.*, 2020). Formation of soil requires thousands of years to develop an inch of soil. In India, the sustainability of crop

production systems has also become a main concern to meet the food demand of the ever-increasing population. About 57% of the total geographical area of India is suffering from different types of land deprivation problems. Long-term degradation impacts on soil carbon dynamics and biological functioning have also been reported by Bhardwaj *et al.*, (2019), underscoring the ecological cost of unsustainable practices. Further, India needs 350 million tons (mt) of food grains to meet the demand of the projected population of 1.48 billion by 2030 (Pathak, 2010).

Soil fertility is the ability of the soil to supply plant nutrient elements required for the optimum growth of plants. It is a natural dynamic property that is influenced by natural and anthropogenic factors. Variations in soil fertility are associated with

nutrient management, particularly under contrasting fertilization regimes (Bhardwaj *et al.*, 2020). The primary objective of soil fertility is to maintain and enhance agricultural yield by improving the physical, chemical and biological health of the soil. Soil fertility is an important factor, which determines the growth and yield of plants (Singh *et al.*, 2018). However, Soil testing assesses the current fertility status and provides information regarding nutrient availability in soils which forms the basis for the fertilizer recommendations for maximizing crop yields and maintaining the optimum fertility in soil year after year. Reduction in available nutrients in the soil is directly associated with soil fertility level which is affected by the blanket application of chemical fertilizers which leads to the deterioration of soil quality and it also reduces agricultural productivity. Loss of nutrients may occur from removal of crops, erosion of soil, and leaching. Comparable nutrient depletion patterns driven by hydrological losses were reported by Singh *et al.* (2014), highlighting the importance of nutrient conservation strategies. Loss of soil quality can also be caused by improper irrigation, excessive fertilizer usage and other cultural practices. Continuous soil cultivation accelerates the breakdown of organic matter. Kushwaha *et al.*, (2020) likewise demonstrated that microbial degradation processes intensify under continuous cultivation, accelerating SOM decline. It facilitates interactions between physical, chemical and biological processes that lower SOM (Yadav *et al.*, 2022). One of the key elements that influence the chemical and biological characteristics of the soil as well as providing plant nutrition is soil organic matter. According to Quinton *et al.* (2010). Patterns of soil carbon variation across landscapes were also explored by Thakur *et al.*, (2020), further reinforcing the significance of SOM in soil functioning.

Soil organic carbon availability is an important component of soil, as soil organic carbon is a building block of soil quality and plant production. Low fertility status in India is a major constraint to achieving higher productivity (SLUSI 2009-10). Similar microclimatic controls on soil carbon and nutrient behaviour were described by Singh *et al.*, (2020). Throughout the growing season, soil fertility may fluctuate due to various inputs such as fertilizers, manure, compost, mulches, amendment material, and production principles and techniques. Bundelkhand region located in the central part of the country is well known for

unexplored, low fertile and poorly managed soil due to excessive drainage, low soil depth, very low water retention capacity and low content of organic matter and crust formation on the soil surface (Srinivasan *et al.*, 2016). Soil–environment interactions affecting nutrient distribution in semi-arid zones were also discussed by Ashwin *et al.*, (2020). Hence, the assessment of the soil fertility status of the area or region is much needed to attain the sustainability of agriculture (Singh and Mishra, 2012). Spatial variability in soil fertility and nutrient status was similarly addressed by Bhardwaj *et al.*, (2021), supporting the application of fertility indices. Soil fertility status can be ranked using applying nutrient index methods and different fertility indicators for the delineation of the area on a soil map (Sahu *et al.*, 2023). Therefore. In the present study, an effort has been made to evaluate of soil fertility status of KVK Farm, Jalaun district of Uttar Pradesh by adopting a nutrient index to categorize soil into fertility groups and prepare a soil fertility map for the KVK farm to find out the recommendation of organic and inorganic fertilizer to the crops of Bundelkhand region (Ahmad *et al.*, 2021).

## MATERIALS AND METHODS

### Experimental site

The present study area covers the KVK Farm, Jalaun district of Bundelkhand, Uttar Pradesh (Fig. 1). The study area is situated in latitude N 26°07'68" and longitude E 79°37'41". The climate of the study area is typically arid to semi-arid with extremely strong summers. The average annual rainfall is about 885 mm, out of which 80% of rainfall is received from June to September. Droughts and long dry spells that occur during the rainy season are the common features in this region which directly affect the *kharif* and *rabi* production. The KVK spreads over an area of 23.06 ha, out of which 20.5 ha of area is cultivable land and the remaining area is a wasteland and covered by infrastructure. Soils of Bundelkhand are characterized by their varying depth, soil texture, colour and topographic situations. There are two main soil groups *i.e.*, Red and Black soils classified into four local soils known as Parwa, Rakar, Kabar and Mar.

### Soil sampling and analysis

The composite soil samples were collected from three-tier depths *i.e.* 0-15 cm, 15-30 cm and 30-45 cm

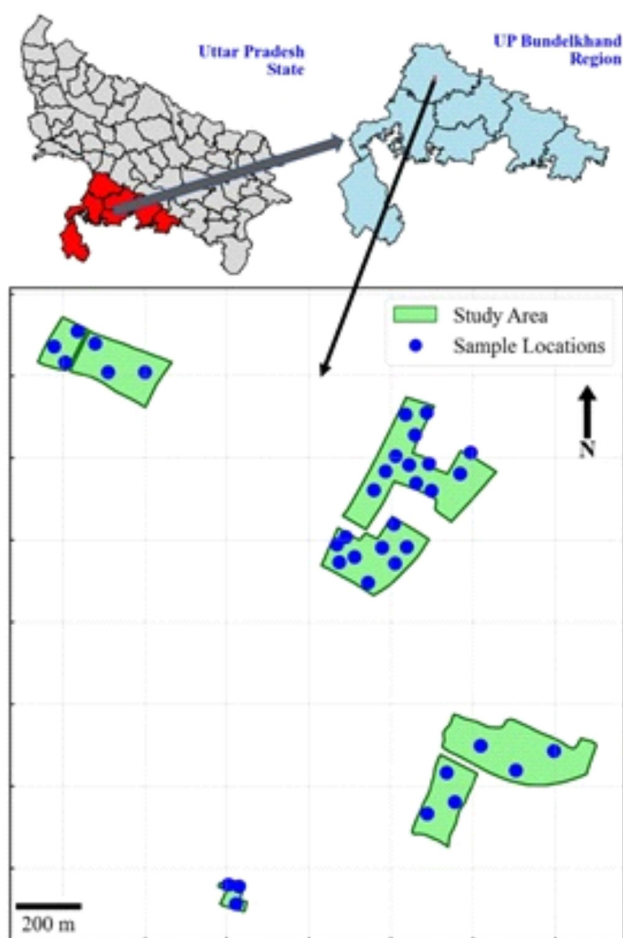


Fig. 1. Map of the Study Area

based on topography, soil type, and slope of the farm from KVK, Jalaun. A total of 108 geo-referenced soil samples were collected in April - May 2023. The coordination points were recorded by GPS. The quartering technique was used for preparation of the soil sample. Collected soil samples were air-dried in a shady place, grinded using a pestle and mortar, sieved through a 2 mm sieve and stored in a plastic polythene bag with proper labelling. The processed soil samples were analyzed for organic carbon by Walkley and Black method (Walkley and Black, 1934), available nitrogen by the alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by Olsen method (Olsen's *et al.*, 1954) using a spectrophotometer. Available potassium was determined by the neutral ammonium acetate method using a flame photometer (Hanway and Heidal, 1952), and available sulphur by 0.15 % calcium chloride method (Williams and Steinberg, 1969). The micronutrients *i.e.* Mn, Cu, Zn and Fe were determined by using the

DTPA method (Lindsay and Norvell, 1978) and available boron by using hot water soluble (Gupta, 1967).

### Nutrient index

Considering the concept of soil nutrient index, the soils of the study area were grouped into three classes low, medium and high nutrient status. The nutrient index was calculated by using Parker's formula (1951).

$$\text{Nutrient Index value (N.I.V)} = \frac{\text{NI} \times 1 + \text{Nm} \times 2 + \text{Nh} \times 3}{\text{NI} + \text{Nm} + \text{Nh}}$$

Where,

$N_1$  - Indicates the number of samples falling in the low class of nutrient status

$N_m$  - Indicates the number of samples falling in the medium class of nutrient status

$N_H$  - Indicates the number of samples falling in a high class of nutrient status

A particular nutrient element having a Nutrient Index Value <1.67 is considered as 'Low' for 1.67-2.33 as 'Medium' and for above 2.33 as 'High' (Ramamoorthy and Bajaj, 1969).

## RESULTS AND DISCUSSION

The present study was conducted to assess Soil Fertility status at KVK Farm, Jalaun district of Bundelkhand (Uttar Pradesh) and Nutrient Index Values for soil nutrients. Thematic map of different soil nutrients of KVK Jalaun is presented in Fig. 2.

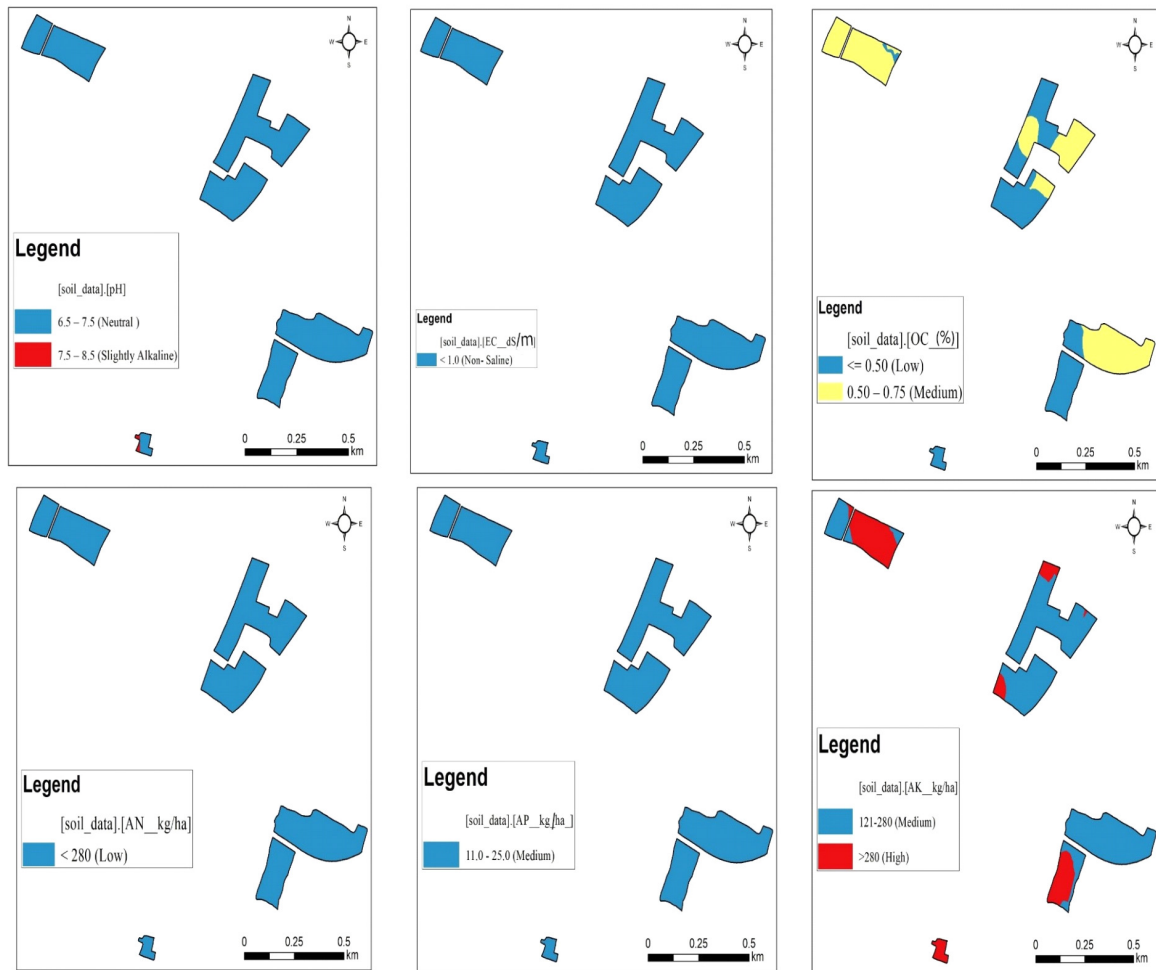
### Nutrient Index value and fertility rating of the study area

The nutrient index (NI) value for each nutrient under study is computed from the number of samples that fall under the high, medium and low categories. Based on the NI values, the fertility rating of the study area is classified as low (<1.67), medium (1.67-2.33) and high (>2.33).

### Nutrient index values for major nutrients

#### Soil organic carbon (SOC)

Soil organic matter plays a key role in influencing the nutrient dynamics in soils. It acts as a sink by boarding the nutrients temporarily through array of biochemical processes ranging from adsorption



**Fig. 2.** Thematic map of soil nutrients of KVK, Jalaun

\*EC: Electrical Conductivity, OC: Organic Carbon, AN: Available Nitrogen, AP: Available Phosphorus, AK: Available Potassium

**Table 1.** Rating chart of nutrient index values

S.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

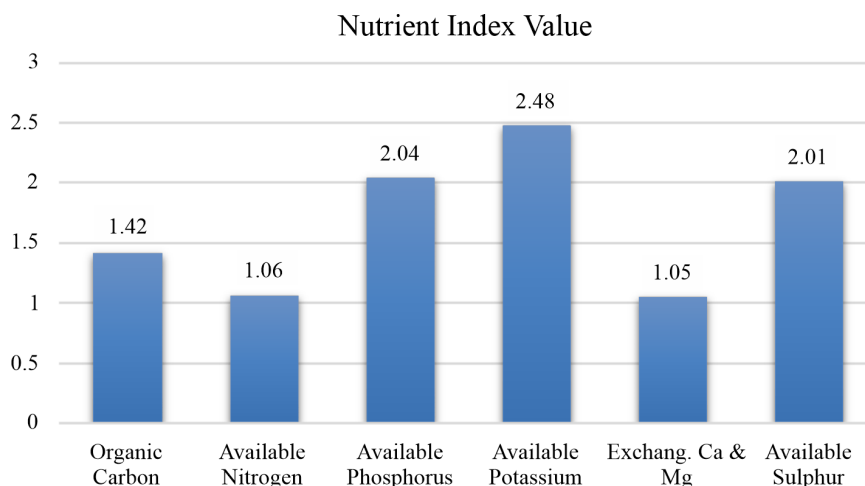
Source: Parker *et al.* (1951)

reactions to organically held plant nutrients play a vital role in sustaining plant nutrient availability (Singh *et al.*, 2024). The nutrient index value of soil organic carbon was 1.46 and categorized as low. Most of the soil samples in low (57%) followed by medium (43%) in soil organic carbon value considering the critical limit of < 0.50% as low, 0.51 to 0.75% as medium and > 0.75% of high organic carbon value (Fig. 3). Similar studies were reported by Khan *et al.* (2017), Chaubey *et al.* (2021) and

Mishra *et al.* (2023).

**Available nutrient (N)**

The NI value of soil organic carbon was 1.06 and categorized as low. Most of the soil samples (94%) having a low in available nitrogen considering the critical limit of < 280 kg ha<sup>-1</sup> as low, 281 to 560 kg ha<sup>-1</sup> as medium and > 560 kg ha<sup>-1</sup> as high (Fig. 3). Similar studies were reported by Tagore *et al.* (2014), Chaubey *et al.* (2021) and Mishra *et al.* (2023).



**Fig. 3.** Nutrient index value of major nutrients

#### ***Available phosphorus (P)***

The value regarding the nutrient index of available phosphorus was 2.04 showing the medium index value. Most of the sample (95%) having a medium in available phosphorus considering the critical limit of  $< 10 \text{ kg ha}^{-1}$  as low,  $11 \text{ to } 25 \text{ kg ha}^{-1}$  as medium and  $> 25 \text{ kg ha}^{-1}$  for high. (Fig. 3) The results were recorded by Patil *et al.* (2017), Singh *et al.* (2018) and Mishra *et al.* (2023).

#### ***Available potassium (K)***

The nutrient index value for available potassium was 2.48 showing a higher nutrient index value. The majority of the soil samples in medium (63%) followed by high (37%) in available potassium value considering the critical limit of  $< 120 \text{ kg ha}^{-1}$  as low,  $121 \text{ to } 280 \text{ kg ha}^{-1}$  as medium and  $> 280 \text{ kg ha}^{-1}$  for high (Fig. 3). Similar studies were reported by Tagore *et al.* (2014), Chaubey *et al.* (2021) and Kumar *et al.* (2019).

#### ***Exchangeable Calcium and Magnesium***

The NI Value for exchangeable calcium and magnesium was 1.05 showing a lower nutrient index value. Most of the soil samples (94%) having the low exchangeable calcium and magnesium considering the critical limit of  $< 10 \text{ meq/100g}$  of soil as low,  $10 \text{ to } 30 \text{ meq/100g}$  of soil as medium and  $> 30 \text{ meq/100g}$  of soil for high (Fig. 3). Similar results were recorded by Mishra *et al.* (2023).

#### ***Available Sulphur (S)***

The NI Value for available sulphur was 2.01 and categorized as medium. Most of soil samples (98%)

having the medium in available sulphur considering the critical limit of  $< 10 \text{ mg kg}^{-1}$  as low,  $10 \text{ to } 20 \text{ mg kg}^{-1}$  as medium and  $> 30 \text{ mg kg}^{-1}$  for high (Fig. 3). Similar findings were reported by Amar and Shanmugasundaram (2020) and Mishra *et al.* (2023).

#### **Nutrient index values for minor nutrients**

##### ***Available iron (Fe)***

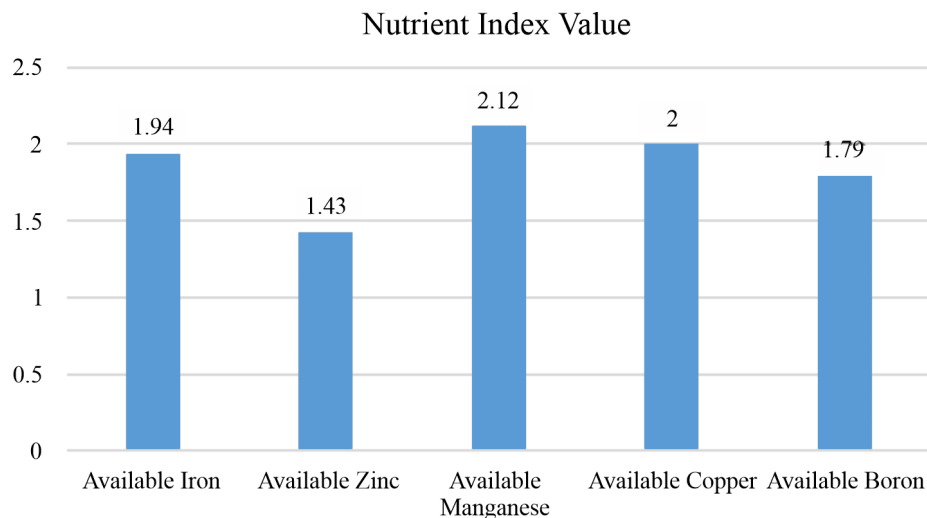
The nutrient index value for available iron was 1.94 and categorized in medium. Most of the soil samples (94.5%) having the medium in available iron considering the critical limit of  $< 4.5 \text{ mg kg}^{-1}$  as low,  $4.5 \text{ to } 10 \text{ mg kg}^{-1}$  as medium and  $> 10 \text{ mg kg}^{-1}$  for high (Fig. 4). Similar findings were reported by Kumar *et al.* (2013) and Prasad *et al.* (2020).

##### ***Available zinc (Zn)***

The NI value for available iron was 1.43 showing a lower nutrient index value. The majority of the soil samples in low (56.48%) followed by medium (43.51%) in available zinc considering the critical limit of  $< 0.6 \text{ mg kg}^{-1}$  as low,  $0.6 \text{ to } 1.0 \text{ mg kg}^{-1}$  as medium and  $> 1.0 \text{ mg kg}^{-1}$  for high (Fig. 4). Similar studies were recorded by Mishra *et al.* (2023).

##### ***Available manganese (Mn)***

The NI value for available manganese was 2.12 and categorized in medium. Most of the soil samples (82.40%) having a medium in available manganese considering the critical limit of  $< 3.5 \text{ mg kg}^{-1}$  as low,  $3.5 \text{ to } 7.0 \text{ mg kg}^{-1}$  as medium and  $> 7.0 \text{ mg kg}^{-1}$  for high (Fig. 4). Similar findings were reported by Kumar *et al.* (2013) and Prasad *et al.* (2020).



**Fig. 4.** Nutrient index value of micronutrients

#### **Available copper (Cu)**

The NI value for available copper was 2.0 and categorized in medium. Most of the soil samples (100%) having a medium in available copper considering the critical limit of  $< 0.2 \text{ mg kg}^{-1}$  as low,  $0.2$  to  $1.0 \text{ mg kg}^{-1}$  as medium and  $> 1.0 \text{ mg kg}^{-1}$  for high (Fig. 4). Similar observations were recorded by Kumar *et al.* (2013), Prasad *et al.* (2020) and Mishra *et al.* (2023).

#### **Available boron (B)**

The nutrient index value for available boron was 1.79 and categorized in medium. Most of the soil samples (79.62%) having the medium in available iron considering the critical limit of  $< 0.5 \text{ mg kg}^{-1}$  as low,  $0.5$  to  $1.0 \text{ mg kg}^{-1}$  as medium and  $> 1.0 \text{ mg kg}^{-1}$  for high (Fig. 3). Similar findings were reported by Kumar *et al.* (2013), Prasad *et al.* (2020) and Mishra *et al.* (2023).

### **CONCLUSION**

The soil fertility status of KVK Farm, Jalaun categorized with the help of Nutrient index value (NIV) for organic carbon, available nitrogen, available zinc and exchangeable calcium & magnesium and showed low categories, showing poor fertility status, whereas nutrient index values of available phosphorus, available sulphur, available copper, available boron, available manganese and available iron were found in medium categories and recorded good fertility status followed by available potassium were found in the high categories and

ranked as high fertility status of respective nutrients in the study area. Therefore, the area needs the adaptation of site-specific nutrient management, use of organics as nutrient sources and appropriate agronomic practices to improve the fertility status and achieve better yield potential.

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### **COMPETING INTERESTS**

The author has declared that no competing interests exist.

### **REFERENCES**

- Ahmad, A., Gupta, A.K. and Kumar, D. (2021). Soil fertility evaluation using nutrient index approach. *Journal of Krishi Vigyan*, 10(1), 276-282.
- Amar, A. and Shanmugasundaram, R. (2020). Nutrient index values and soil fertility ratings for available sulphur and micronutrients of Tiruchirappalli district of Tamil Nadu, India. *International Journal of Current Microbiology and Applied Sciences*, 9(3), 337-347.
- Ashwin, H.S., Rekha, M.V., Champa, B.V., Alur, A.S., Nagaraja, M.S. and Bhardwaj, A.K. (2020). Secondary salinization risks associated with irrigation water under changing climate scenarios. *Environmental Monitoring and Assessment*, 192(11), 1-14.
- Bhardwaj, A.K., Katoch, K.K. and Nagaraja, M.S. (2015). Enhancing harvested rainwater productivity through organic manuring and irrigation scheduling. *Journal of Soil and Water Conservation*, 14(2), 155-161.

- Bhardwaj, A.K., Rajwar, D., Basak, N., Bhardwaj, N., Chaudhari, S.K., Bhaskar, S. and Sharma, P.C. (2020a). Plant available nitrogen at critical growth stages of rice and its relationship with soil biological activity under nutrient management systems. *Journal of Plant Nutrition*, 43(18), 2756–2768.
- Bhardwaj, A.K., Rajwar, D., Mandal, U.K., Ahamad, S., Kaphaliya, B., Minhas, P.S. and Sharma, P.C. (2019). Impact of carbon inputs on soil carbon fractions, sequestration and biological responses under major nutrient management practices in rice–wheat systems. *Scientific Reports*, 9, 10345.
- Bhardwaj, A.K., Rajwar, D., Yadav, R.K., Chaudhari, S.K. and Sharma, D.K. (2021). Nitrogen availability and use efficiency in wheat crop as influenced by the organic-input quality under major integrated nutrient management systems. *Frontiers in Plant Science*, 12, 634448.
- Chaubey, C., Chaubey, A.K., Mishra, A., Singh, N., Shukla, G. and Kumar, S. (2021). Assessment of soil fertility status of Kanwara minor left canal command area in Banda district of Bundelkhand using Nutrient Index Values. *Current Journal of Applied Science and Technology*, 40(4), 98-104.
- Gupta, U.C. (1967). A simplified method for determining hot-water soluble boron in podzol soils. *Soil Science*, 103, 424-428.
- Hanway, J.J. and Heidel, H. (1952). Soil analysis methods as used in Iowa State College Soil Testing Laboratory. *Iowa Agriculture*, 57, 1-31.
- Khan, M.H., Kumar, S., Kumar, A. and Mehra, 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. *International Journal of Chemical Studies*, 5(6), 73-80.
- Kumar, M., Kar, A., Raina, P., Singh, S.K., Moharna, P.C. and Chauhan, J.S. (2019). Spatial variability of available soil nutrients in the Shekhawati region of Thar Desert, India. *Journal of the Indian Society of Soil Science*, 67, 21-33.
- Kumar, P., Kumar, A., Dyani, B.P., Kumar, P., Shahi, U.P. and Singh, S.P. (2013). Soil fertility status in some soils of Muzaffarnagar district of Uttar Pradesh, India, along with the Ganga canal command area. *African Journal of Agricultural Research*, 8(14), 1209-1217.
- Kushwaha, P., Kashyap, P.L. and Bhardwaj, A.K. (2020). Bacterial endophyte-mediated tolerance to salinity and nutrient stress. *World Journal of Microbiology and Biotechnology*, 36(9), 1–15.
- Lindsay, W.L. and Norvell, W.A. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Science Society of America Journal*, 42, 421-428.
- Mishra, R. (2023). Soil characterization of KVK farm, Hamirpur using geo-statistical tools. Master's thesis, Banda University of Agriculture and Technology, Banda, India.
- Mishra, S., Kumar, D., Gupta, A.K. and Kumar, S. (2023). Soil fertility status of KVK and RARS Belatal of Mahoba district under Bundelkhand region of Uttar Pradesh. *Journal of Soil and Water Conservation*, 22(4), 427-432.
- Olsen, S.R., Cole, C.V., Watanabe, F.S. and Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *United States Department of Agriculture Circular*, 939, 1-19.
- Parker, F. W., Nelson, W.L., Winters, E. and Miles, I.E. (1951). The broad interpretation and application of soil test information. *Agronomy Journal*, 43(3), 105-112.
- Pathak, H. (2010). Trend of fertility status of Indian soils. *Current Advances in Agricultural Sciences*, 2(1), 10-12.
- Patil, S., Kumar, K.S.A. and Srinivasamurthy, C.A. (2017). Soil fertility status and nutrient index for primary nutrients in the Western Ghats and Coastal Karnataka under different agro-ecological systems. *Asian Journal of Soil Science*, 12(2), 314-319.
- Prasad, M., Mahawer, S.K., Govindasami, P. and 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.
- Quinton, J.N., Govers, G., Van Oost, K. and Bardgett, R.D. (2010). The impact of agricultural soil erosion on biogeochemical cycling. *Nature Geoscience*, 3, 311-314.
- Ramamoorthy, B. and Bajaj, J.C. (1969). Available nitrogen, phosphorus and potassium status of Indian soils. *Fertilizer News*, 14, 25-36.
- Sahu, D., Srivastava, L.K., Porte, S. S., Jatav, G.K. and 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 Change*, 13(10), 2468-2473.
- Singh, A., Kumar, D., Sah, D., Mishra, A. and Gupta, A.K. (2024). Effect of organic manures on soil nutrients, growth and yield of sesame (*Sesamum indicum* L.) in Bundelkhand region of Uttar Pradesh. *Journal of the Indian Society of Soil Science*, 72(1), 126-130.
- Singh, A.K., Arora, S., Singh, Y.P., Bhardwaj, A.K. and Singh, D. (2014). Water and energy use pattern under different irrigation systems in wheat grown on partially reclaimed sodic soils. *Journal of Soil and Water Conservation*, 13(3), 234–240.

- Singh, M., Kaur, S., Devi, S. and Bhardwaj, S.K. (2020). Influence of microclimatic variables on crop productivity in pea. *Journal of Agrometeorology*, 22(2), 200–206.
- Singh, R.P. and Mishra, S.K. (2012). Available macronutrients (N, P, K and S) in the soils of Chiraigaon block of district Varanasi (Uttar Pradesh) in relation to soil characteristics. *Indian Journal of Scientific Research*, 3(1), 97-100.
- Singh, S.P., Singh, S., Kumar, A. and Kumar, R. (2018). Soil fertility evaluation for macronutrients using Parker's nutrient index approach in some soils of Varanasi district of eastern Uttar Pradesh, India. *International Journal of Pure and Applied Bioscience*, 6(5), 542-548.
- SLUSI. (2010). *Annual report (2009-10)*. Soil and Land Use Survey of India, Kodigehalli Road, Bengaluru, India.
- Srinivasan, R., Tripathi, S.B., Rai, A.K., Das, S.K., Rao, D.V. K. N. and Ghosh, P.K. (2016). *Strides in soil research: Soil health management and fodder production*. ICAR-Indian Grassland and Fodder Research Institute, Jhansi, India, pp. 21-91.
- Subbiah, B.V. and Asija, G.L. (1956). A rapid procedure for the determination of available nitrogen in soils. *Current Science*, 25, 259-260.
- Tagore, G.S., Bairagi, G.D., Sharma, R. and Verma, P.K. (2014). Spatial variability of soil nutrients using geospatial techniques: A case study in soils of Sanwer tehsil of Indore district of Madhya Pradesh. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40(8), 1353.
- Thakur, V., Singh, M. and Bhardwaj, S.K. (2020). Soil organic carbon stocks under different vegetation conditions in western Himalayas. *Environmental Monitoring and Assessment*, 192(6), 345–356.
- Walkley, A. and Black, I.A. (1934). An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*, 37, 29-38.
- Williams, C.H. and Steinbergs, H. (1969). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research*, 10, 340-352.
- Yadav, K.K., Mali, N.L., Kumar, S., Surya, J. N., Moharana, P.C., Nogiya, M. and Meena, R.L. (2022). Assessment of soil quality and spatial variability of soil properties using geo-spatial techniques in sub-humid southern plain of Rajasthan, India. *Journal of the Indian Society of Soil Science*, 70(1), 1-17.