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Assessment of the Soil Physio-chemical Properties and Nutrient Dynamics in Niyamtabad Block, Chandauli District, Uttar Pradesh, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Abstract

A study was conducted to evaluate soil fertility and quality parameters of Niyamatabad Block of Chandauli district Uttar Pradesh (U.P.) which is located at 25.26° N latitude and 83.26° E longitude and at elevation of 80.7 m above mean sea level (AMSL) in the centre of Gangatic plain of Northern India. A total of 60 soil samples were collected from the farmer's field from different villages of

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Niyamatabad Block. Physico-chemical property analyses showed average bulk density of 1.36 mg/m^3 whereas water holding capacity ranged from 32.62 to 51.70 %, pH ranged from 6.3 to 8.8, EC ranged from 0.14 to 0.85 dSm-1 and organic carbon content ranged from 0.17 to 0.93 % with low to medium organic carbon content in 80% of the soil samples. Macronutrient analysis showed low range for nitrogen, high phosphorus and medium for potassium and sulphur with mean values of 140.91 Kg/ha, 31.27 kg/ha respectively whereas mean value of potassium (188.81kg/ha) and for sulphur mean value (15.85 mg/kg). Micro-nutrient analysis found range for copper and manganese with values ranging from 1.63 to 6.1 mg/kg and 8.5 to 36.1 mg/kg respectively, with iron in the medium to high range (17.31 to 152.2 mg/kg) while available zinc (0.64 to 2.08 mg/kg) was in the high range in the tested samples. It is expected that the current study will assist the farmers in the study area by offering the necessary instructions for managing soil fertility over the long term, improving soil quality, and creating crop varieties that can flourish without reducing production.

Keywords: Soil physiochemical properties; macronutrients; micronutrients; soil fertility; nutrient status.

1. Introduction

Soil provides a medium for the growth of plants as well as support for humans and animals. Soil health, also known as soil quality, is defined as the soil's ongoing capacity to function as a vital living ecosystem that supports humans, plants, and animals. The majority of the time, chemical fertilisers, organic manures, and composts are added to the soil to help plants achieve their nutritional needs (Arévalo-Gardini et al., 2015). In terms of morphology, which varies from parent material, chemical composition, biological characteristics, and physical makeup, soil is the natural body of minerals and organic ingredients that have diversified into horizons of varying depths below (Roy, 2014). The plant requires essential nutrients to complete its life cycle, so an essential nutrient deficiency makes it impossible for the plant to complete the vegetative and reproductive stages of its life cycle. Therefore, it will be important to analyse the soils in order to identify the nutrients that are lacking and to supply the appropriate amount. Plants require comparatively more macronutrients than micronutrients (Grover et al., 2016, Subbiah and Asija, 1956).

Chlorophyll, nucleic acids, proteins, amino acids, and enzymes all contain nitrogen, which stimulates vegetative growth and root development. Phosphorus helps plants store energy and promotes the growth of roots and seeds. Potassium functions as an enzyme activator, aids in the production and transport of sugars and carbohydrates, aids in stomata function, and helps plants withstand disease and drought. Secondary nutrients like calcium, magnesium, and sulfur are crucial for plant growth and development because they encourage the formation of nodules in the roots of nitrogen-binding leguminous plants (Thaker et al., 2023). “The ability of soil to sustain plant and animal productivity, maintain or improve water and air quality, and promote plant and animal health within ecosystem and land-use boundaries” (Anonymous, 2015). Uttar Pradesh is located in the fertile Indo-Gangetic plains region and, it is a significant contributor to the food security of the nation. Niyamtabad block is located in Chandauli district in Uttar Pradesh.

Finding the right amount and kind of fertilisers, manures, or compost to employ to increase soil productivity for a given crop requires a thorough understanding of the physico-chemical and nutritional condition of the soil. It assists in preventing monetary losses from applying fertiliser needlessly. In this regard, the Niyamtabad block's comprehensive soil survey of several villages—Jalilpur, Kuri, Rema, Godhna, Dulhipur, Bahuara, Saidpur, and Rasulpur were selected for investigation in order to produce a site-specific database for the optimal planning and effective utilisation of soil nutrient status in Chiraigaon block, Varanasi, Uttar Pradesh.

2. Materials and Methods

2.1 Description of Study Location

2.1.1 Experimental Site

Niyamtabad block is one among the 9 blocks in Chandauli district which is located in the centre of the Gangetic plain of northern India, in the eastern part of the state of Uttar Pradesh, at an elevation of 80.71 metres form mean sea level (Yadav et al.). From Niyamtabad block 60 representative surface soil samples were collected from cultivated fields of various villages, namely Jalilpur, Kuri, Rema, Godhna, Dulhipur, Bahuara, Saidpur and Rasulpur.

2.1.2 Weather and Climate

The climate of the Niyamtabad block of Chandauli is mild and generally warm and temperate. The rainfall in Chandauli is significant, with precipitation even during the driest month. The Köppen-Geiger climate classification is subhumid subtropical climate Cwa (Chen et al., 2023). In Chandauli, the average annual temperature is 26.7 °C and the annual rainfall is around 1069.6 mm, with the lowest precipitation in April (average of 6 mm).

2.1.3 Soil Characteristics

The soils of Chandauli districts resembles that of the alluvial plains of the river Ganga is dominated by the Inceptisols order. The soil characteristics here are distinct because they are formed by the older alluvium and vary from Primarily Silty Clay Loam to Clay, sodic or saline soil, wasteland and ravines**.** The soil fertility status ranges from moderate to poor. The major cropping rotation followed in the district are rice- wheat, Crops- arhar, bajra, lentil, potato, mustard, pea, and vegetables.

2.2 Methods of Sampling and Processing

The soil samples were randomly collected from each selected villages of Chandauli districts from 0-15 cm depth by making a V-shape notch which were mixed thoroughly, and 500 gm of soil samples were collected for analysis from each site.

Collected soil samples were air-dried and then crushed and ground with a wooden roller and then it was sieved by using a 2.0 mm sieve. Processed samples were put in a labelled polythene bag transported to laboratory for analysis.

2.2.3 Physical and Chemical Analysis of Soil Samples

Various physical-chemical parameters such as Water holding capacity, bulk density, pH, electrical conductivity and organic carbon were determined in the collected soil samples.

2.2.4 Determination of Water Holding Capacity and Bulk Density

The bulk density was determined with the help of Pycnometer described by Black (1965).

$$\text{Bulk density} = \frac{\text{Mass of the soil}}{\text{Volume of the soil}}$$

2.2.5 Determination of Water Holding Capacity

Water holding capacity of the soil samples were done according to Piper's Method (1966), by using following equation-

$$\text{WHC}(\%) = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Dry weight}} X\ 100$$

2.2.6 Determination of Soil pH and Electrical Conductivity (EC)

Soil pH was determined by using the digital pH meter illustrated by Jackson, in (1973). In the soil, soluble salt was determined by using EC meter described by Jackson, 1973 (in dSm-1).

2.2.7 Determination of Organic Carbon

Organic carbon of soil sample was estimated by Walkey and Black method of wet oxidation (Walkey and Black, 1934), using the formula-

$$\text{OC}(\%) = \frac{\text{B} - \text{C}}{\text{weight of soil}} X\ 0.003\ X\ 100$$

Where,

A = Volume of 0.5N ferrous ammonium sulphate (FAS) required to neutralise 10 ml of 1N of $K_2Cr_2O_7$ i.e. blank titration (blank reading)

B = Volume of 0.5N FAS needed for titration of soil sample (reading with soil)

2.2.8 Determination of Available Nitrogen

The available nitrogen present in soil was determined with the help of Kjeldahl semi auto-analyser which was described by Subbiah and Asija (1956).

Available N (kg ha-1)

$$= \frac{(\text{S} - \text{V})\ X\ 0.002\ X\ 14\ X\ 2.24\ X\ 106}{1000\ \text{X}\ 5}$$

Where,

S = Sample titration reading
V = Blank titration reading

2.2.9 Determination of Available Phosphorus

Estimation of available phosphorus content in soil samples was determined by Olsen's method for neutral and alkaline soil using 0.5 M NaHCO3 solution (pH 8.5).

2.2.10 Determination of Available Potassium

Estimation of available potassium in soil samples was done with the help of a flame photometer (Schollenberger and Simon, 1945), and by using neutral normal ammonium acetate.

2.2.11 Determination of Available Sulphur

Estimation of sulphur in the soil by Turbidity method (Chesnin and Yien, 1950). Available sulphur (mg kg-1)

$$\mathrm{S(mg\ /kg)} = \mathrm{R\ X}\frac{50}{10}X\ 0.1$$

Where, R stands for S content in µg as read on X-axis

2.2.12 Available Micronutrient

Cationic micronutrients iron, zinc, copper and manganese in the soil samples were measured on the atomic absorption spectrophotometer.

2.2.13 Evaluation of Soil Nutrient Status

To compare the levels of soil fertility of one area with those of another area soil fertility then it was necessary to obtain a single value for each nutrient. Nutrient index (N.I) value is a measure of nutrient supplying capacity of soil to plants.

Nutrient Index (N.I.) = (NL × 1 + NM × 2 + NH × 3) / NT

Where,

NL Indicates number of samples falling in the low class of nutrient status.

NM Indicates number of samples falling in medium class of nutrient status .

NH Indicates number of samples falling in the high class of nutrient status.

NT Indicates the total number of samples analysed for a given area

3. Results and Discussion

3.1 Soil Fertility Status of Physio-Chemical Parameters

This study showed that the bulk density of soil samples ranged from 1.19 to 1.47 Mg m^{-3} with a mean value of 1.35 Mg m^{-3} (Table 1). This study showed that the bulk density depended on the consolidation of the soil and compaction, but it is negatively correlated to the organic matter content. Similar results were also recorded by Nasar *et al.,* (2024). Soil samples collected from study locations showed water holding capacity from 32.63 to 51.67 %, with an average value of 41.53 % (Table 1). The standard deviation of water holding capacity was 4.4 and the coefficient of variation was 10.5%. The result showed that variation in water holding capacity was probably due to organic carbon content in the soil (Rahman et al., 2024).

The values of pH ranged from 6.25 to 8.8, with a mean value of 7.54, an SD value of 0.64 and a CV value of 8.5 % (Table 1). The pH of the cultivated lands of the Niyamtabad block of Chandauli district was mostly (61.7 %) slightly alkaline in reaction, while 31.6% of the area was moderately alkaline and the rest 6.7 % area was near to neutral. The EC of soil samples ranged from 0.15 to 0.85 dSm-1 with an average value of 0.44 dSm-1 with standard deviation and a coefficient of variation of 0.21 and 47.44 %, respectively (Table 1). The results showed that 100 % of the samples were in the acceptable range. The organic carbon content of soil samples ranged from 0.18 to 0.93 %, with a mean value of 0.57 % (Pandey et al., 2020) (Table 1). The standard deviation of organic carbon content was 0.19, and the coefficient of variation was 34.35. The lowest organic carbon value was observed at the Bahuara village, whereas the highest value was observed at Jalilpur village of Chiraigaon block. The majority of the soil samples were found to be low to medium range in organic carbon (80 %) content, which might be due to low moisture content in the soil and high temperature, which could increase decomposition processed by microorganisms and enzymes and decrease the accumulation of organic matter in the soil.

3.2 Status of Available Primary and Secondary Macronutrients in the Soil

Nitrogen content in soil samples ranged from 84.07 to 205.21 kg ha-1 with a mean value of

140.915 kg ha-1 (Table 2). The standard deviation and coefficient of variation of the available nitrogen were 28.63 and 20.32 %, respectively. The lowest nitrogen content was observed in Kuri, while the highest nitrogen content was in Jalilpur village. The nitrogen content of the study region is low, probably due to low organic carbon content present in the soil (Singh, 2018). Available phosphorus content of soil samples ranged from 12.12 to 63.18 kg ha-1 with an average value of 31.27 kg ha-1 (Table 2). The standard deviation and coefficient of variation of the available nitrogen were 12.99 and 41.53 %, respectively. About 50% of phosphorus is found in organic form and decomposition of the organic matter produces humus, which forms complexes with Al and Fe and protects the P fixation (Singh and Mishra, 2012). Available potassium content of soil ranged from 107.29 to 348.55 kg ha-1 with a mean value of 188.8 kg ha-1 (Table 2). The lowest phosphorus value was observed at Godhna, while the highest was at Jalipur village, with SD and CV value of 74.77 and 39.6 %, respectively. In the study region, potassium content is high, may be due to the presence of elite, rich potassium minerals found in the soil.

As can be seen in Table 3, the Status of available sulphur content of the soil samples ranged from 3.09 to 55.8 mg kg-1 with an average value of 15.84 mg kg-1. More than 41 % sulphur were found low range category in the region (Singh et al., 2015).

3.3 Status of Available Micronutrients in the Soil

In-intensive cropping systems, the use of harmful fertilisers and high-yielding crop varieties leads to micronutrient deficiency in the soil, so it is necessary to monitor the micronutrient (Fe, Cu, Zn, Mn) concentration in the soil. The analysed data of the micronutrients of soil are given in Table 3.

The values of iron in the studied samples ranged from 17.31 to 152. 23 with a mean value of 73.19% were 100% in high, and 0 % were in low iron concentration. Similar results were reported by Singh et al., (2016). The values of copper in the studied samples ranged from2.2 to 4.08 mg kg-1 with a mean value of 3.14 mg kg-1 (Table 3). The values of standard deviation and coefficient of variation of Cu were 0.51 and 16.27 %, respectively. Out of total 60 soil samples, 100 % of samples were high in available copper content as per the critical limit suggested by Lindsay and Norvell, (1978). The values for Zn in the soil samples ranged from 0.58 to 19.62 mg kg-1 with a mean value of 7.89 mg kg-1 (Table 3).

Table 1. Statistical analysed data on physio-chemical parameters of soil

Soil parameter	min	max	mean	SD	CV
BD (Mg m^{-3})	1.192839	1.478625	1.35539	0.067049	4.946812
WHC (%)	32.62352	51.67285	41.53487	4.352643	10.47949
pH	6.255696	8.79086	7.54	0.643066	8.528727
EC (dSm^{-1})	0.147648	0.849274	0.4385	0.208034	47.44209
OC (g kg^{-1})	1.775228	9.318349	5.698916	1.957946	34.35647

Table 2. Statistical analysed data on macronutrients of soil

Soil parameter	min	max	mean	SD	CV
N (kg ha^{-1})	84.06725	205.8628	140.9155	28.63527	20.32088
P (kg ha^{-1})	12.12328	63.17879	31.2705	12.98904	41.53769
K (kg ha^{-1})	107.2288	348.5521	188.816	74.77211	39.60052
S(mg kg^{-1})	3.095325	55.8739	15.8455	11.9902	75.66946

Table 3. Statistical analysed data on available micronutrients of soil

Soil parameter	min	max	mean	SD	CV
Cu (mg kg^{-1})	1.630882	6.093641	3.416	1.330711	38.95523
Mn (mg kg^{-1})	8.538282	36.35634	15.189	6.918801	45.55139
Fe (mg kg^{-1})	17.3195	152.2336	73.198	36.29676	49.5871
Zn (mg kg^{-1})	0.633812	2.082962	1.0758	0.317078	29.47374

Table 4. Nutrient Index (NI) values of Niyamtabad block of Uttar Pradesh

No.	nutrient	NIV	Status
1	N	1	Low
2	P	2.65	High
3	K	2.1	Medium
4	S	1.78	Medium
5	Zn	2.32	High
6	Fe	3	High
7	Mn	3	High
8	Cu	3	High

The values of standard deviation and coefficient of variation of zinc were 5.32 and 67.4 %, respectively. Out of 60 soil samples, 31.67% of the samples were high in zinc, 68.33% had medium in Zn content. Values of manganese content in soil samples ranged from 3.08 to 56.1 mg kg-1 with an average value of 26.37 mg kg-1. The values of standard deviation and coefficient of variation were 9.68 and 36.74 %, respectively. 100 % of soil samples are high in available Mn content, (as per the critical limit suggested by Lindsay and Norvell, (1978).

3.4 Soil Nutrient Index Value

The nutrient index approach is used to calculate the nutrient supplying capacity of soil to plants. This index measures soil fertility status based on the sample percentage in each of three classes i.e. low, medium and high. The nutrient index values for the Niyamtabad block Chandauli district were medium for organic carbon and low in nitrogen and high in phosphorus and medium for potassium and high in micronutrient cations (Fe, Cu, Zn, Mn) (Table 4).

4. Conclusion

Based on the experimental results, it is concluded that, in the soils of Niyamatabad block of Chandauli district, bulk density was observed low for high organic carbon content soil and variation in water holding capacity was observed with organic carbon content in the soil. The results showed that 80 % of soil samples had low to medium organic carbon content, whereas 20% of soil samples had high organic carbon content. According to the Nutrient Index value, nitrogen content was low, whereas potassium and sulphur content lie in the medium category and the status of available potassium and micronutrient zinc, iron, manganese and copper content in the high category. Since nitrogen is actually thought to be the most crucial element for promoting plant growth, it is advised to apply chemical fertilizer to high-yielding crops along with composted and green manure. It is advised to add organic amendments that are rich in phosphorus, such as raw bone meal and poultry manure, to soil with low phosphorus concentration. This should boost the soil's phosphorus availability. It is advised to use gypsum fertilizer or poultry manure if the soil has a low sulfur concentration. A sufficient amount of potassium, such as that present in pig dung, is advised to be added to the soil since it aids in the soil's resistance to disease and drought. The micronutrients (Zn, Cu, Fe, Mn) content in the soil was in the high category. Farmers may find the results of this study helpful in improving the quality of their produce, boosting agricultural yields by conserving soil, and protecting the environment.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

Competing Interests

Authors have declared that no competing interests exist.

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