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Manisha Shukla
Department of Biotechnology, Pandit S.N. Shukla University, Shahdol, Madhya Pradesh, India

Shilpi Mishra
Department of Biotechnology, Pandit S.N. Shukla University, Shahdol, Madhya Pradesh, India

Anjali Singh Maravi
Department of Biotechnology, Pandit S.N. Shukla University, Shahdol, Madhya Pradesh, India

Pradeep Kumar Rana
Soil Testing Lab (Mandi), Shahdol, Madhya Pradesh, India

Rohit Kumar Vishwakarma
Department of Biotechnology, Pandit S.N. Shukla University, Shahdol, Madhya Pradesh, India

Corresponding Author:
Manisha Shukla
Department of Biotechnology, Pandit S.N. Shukla University, Shahdol, Madhya Pradesh, India

Assessing agricultural potential and environmental sustainability through quantification of soil macronutrients

Manisha Shukla, Shilpi Mishra, Anjali Singh Maravi, Pradeep Kumar Rana and Rohit Kumar Vishwakarma

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Abstract
This study presents an analysis of soil properties across various sampled locations of Nawalpur village, Shahdol, focusing on pH levels, electrical conductivity, organic carbon content, as well as nitrogen, phosphorus, and potassium levels. The findings reveal significant variations in soil characteristics, which play a crucial role in agricultural productivity. Notably, pH levels range from slightly acidic to neutral, impacting nutrient availability for plant growth. Additionally, the study highlights variations in macronutrient levels and their implications for crop development. Understanding these soil properties is essential for informed agricultural management practices and sustainable crop production.

Keywords: Soil, crop, macronutrients, nitrogen, phosphorus, potassium

Introduction

Soil serves as the cornerstone for crop growth and ecosystem stability, with its nutrient composition being crucial for sustaining surface ecosystems. The levels of macro and micro-nutrients in soil not only indicate its fertility but also serve as vital indicators for evaluating crop yield. The imbalance in soil nutrients can significantly hamper crop production and yield. Hence, it's crucial to systematically evaluate and monitor soil physical, chemical and nutrient status to identify priority areas for implementing effective nutrient management practices. This assessment helps avoid overuse of fertilizers, which could otherwise lead to environmental deterioration.

Nitrogen, phosphorus, and potassium are the main components of soil fertilizer that are important for plant and animal growth and development. Soil analysis for NPK content is a key indicator of soil quality and helps determine how much fertilizer is needed. However, excessive use of fertilizer can be toxic to the soil due to nutrient imbalance. Therefore, the application of fertilizer composition in accordance with the needs of the soil is highly recommended so that the yields become better without damaging the soil.

Understanding the variations in soil pH and other essential nutrients, including nitrogen, phosphorus, and potassium, is vital for informed decision-making in crop selection and nutrient management practices. This research aims to assess soil properties across sampled locations, providing valuable insights into soil fertility and its implications for sustainable agriculture. By examining variations in soil characteristics, this study seeks to contribute to enhanced agricultural productivity and resource utilization.

Materials and Methods

The methodology employed in this research involves a systematic approach to assess the soil macronutrient status in the Nawalpur Village, Shahdol. The following steps were followed:

Soil Sampling: Soil samples were collected from Twenty-five different locations in Nawalpur village (23.338726 Latitude and 81.3502461 Longitude). These samples were obtained from the 30 cm depth in the field, were cleared of any herbaceous and plant residues. These samples were gathered from 25 distinct points within Nawalpur village in Shahdol, with each location spaced approximately 2 kilometers apart.

Soil Analysis: The soil samples underwent a process of air-drying, grinding, and sieving to ensure they passed through a 2-mm sieve. Next, these samples were analyzed in the laboratory for pH, electrical conductivity (EC), and nutrient content (organic carbon, nitrogen, phosphorus, potassium). Soil pH was measured electrometrically by creating a soil-water suspension and using a glass electrode connected to a pH meter. The electrode measures the electrical potential difference between the soil solution and a reference electrode. The pH meter then converts this potential difference into a pH value, providing a direct measurement of the soil's acidity or alkalinity [1]. The electrical conductivity of aqueous soil was measured using a conductivity meter [2]. Organic carbon testing in soil was conducted using the volumetric Walkley-Black method. Soil samples were prepared by air-drying and grinding before digestion with a potassium dichromate solution. Titration with ferrous ammonium sulfate determined the amount of unreacted dichromate, allowing calculation of organic carbon content [3]. The nitrogen content of soil was measured using the Kjeldahl method. In this method, a known quantity of soil sample is digested with concentrated sulfuric acid in the presence of a catalyst. The digested solution is then distilled with a strong base. The excess acid in the receiving flask is titrated with a standardized solution of a strong base using a suitable indicator. The endpoint of the titration is reached when the acid-base reaction is complete, and the volume of base required for neutralization is recorded [4]. The Olsen's method was conducted for determining phosphorus availability in neutral to alkaline soils [5]. Potassium content was determined by using Flame photometer [6]. All statistical analyses were performed using GraphPad Prism software version 6.0 (San Diego, CA, USA).

Result

Table 1 presents measured value for each soil samples in a laboratory. The data provided in the table showcases the pH levels, electrical conductivity, organic carbon content, as well as the levels of nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) for each soil sample. The values indicate variations in soil properties across the sampled locations, which can significantly influence agricultural productivity. pH levels ranging from 6.0 to 7.5 suggest a slightly acidic to neutral soil environment, which is crucial for nutrient availability to plants. Among 25 samples, sample 6, 8, 14, 16, 18 and 22 showed acidic pH level (Figure 1). Electrical conductivity values vary between 0.14 to 0.46 µhos/cm, indicates the soil's ability to conduct electricity, often correlated with its salinity and nutrient content. It found normal in all the samples (Figure 2).

Organic carbon percentages, ranging from 0.15 to 0.75 (Figure 3), reflect the soil's organic matter content, crucial for soil structure, water retention, and nutrient cycling. Nitrogen levels vary from 43 to 285 Kg/ha in sample soils, essential for plant growth and protein synthesis. Sample 1, 3, 7, 12, 15 and 19 observed medium level of Nitrogen when compared to others (Figure 4). Potassium levels fluctuate from 250 to 358.1 Kg/ha, influencing enzyme activation, water regulation, and disease resistance in plants. Medium potassium level were observed in sample 12, 23 and 24 (Figure 5). Phosphorus content ranges from 2.25 to 9.47 Kg/ha, impacting root development, flowering, and fruiting (Figure 6).

Discussion and Conclusion

The study area is an agricultural dependent village. Soil nutrients are important for the yield of crops. Soil physical properties and macro-nutrients content influence greatly the plant growth and development. Soil pH is a good indicator of how suitable a soil is for plant growth. The optimal soil pH for most crops typically falls within the range of 6.0 to 7.5, which promotes optimal nutrient availability and supports robust root growth. When soil pH is outside of the ideal range, nutrients like nitrogen, phosphorus, and potassium become less available to crops. Below a pH of 6, nutrients like iron, copper, and aluminum become more available, this can sometimes be toxic to crops [7]. In this study, all the soil samples showed optimal pH range.

In an agricultural setting, knowing the concentration of nutrients can help food producers know when to add fertilizer, how much to add, and which nutrients need supplemented and in what amount. High nitrogen levels are also particularly useful for non-flowering plants because nitrogen is required for any green part of plants. High nitrogen levels can suppress flowering however, if they remain higher than phosphorus levels. Phosphorus controls flowering in plants and is important to any plant production involving flowering or fruiting plants and phosphorus is often added to soils or directly to plants before and during flowering and fruiting life-cycle stages to increase agricultural yields. Potassium is involved in catalyzing many chemical reactions required to support plant life including drought tolerance and moisture regulation. Low potassium soils will likely need to be irrigated if soil amendment is not possible [8].

Nutrient concentration can also inform of nutrient deficiencies or surpluses that can be detrimental to plant growth. If a nutrient is too high, amendments can be performed to reduce a surplus, such as adding mulch or tilling the soil. If nutrients are too low to support plant production, fertilization can be used to add nutrients in an amount needed for a specific crop. It is important to adapt sound nutrient management practices, which balance inputs and outputs of nutrients.

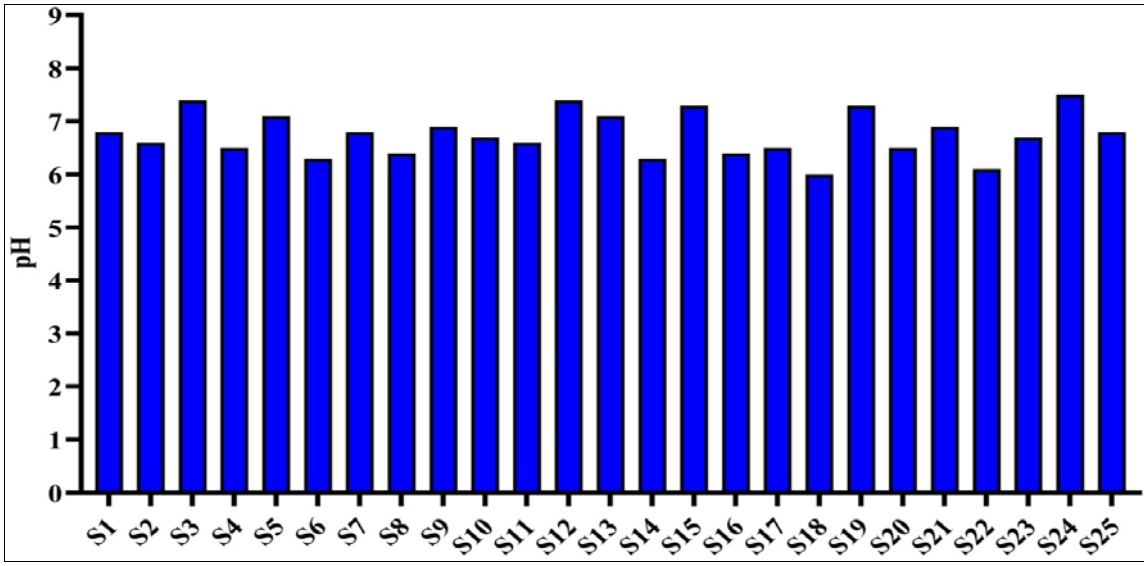

Fig 1: pH levels in 25 different samples of Nawalpur Village Shahdol.

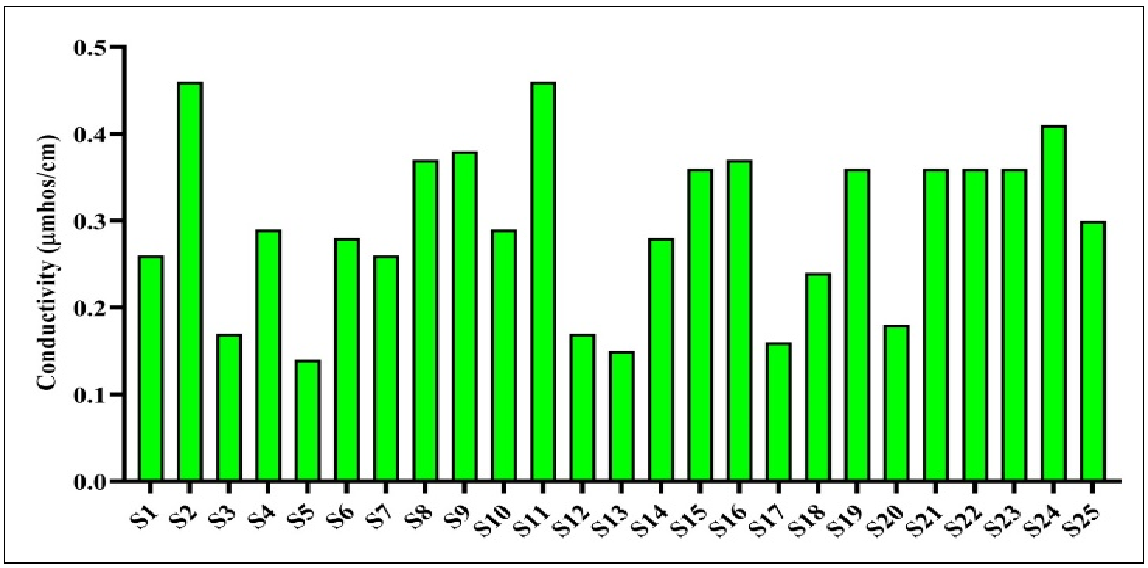

Fig 2: Electrical conductivity in 25 different samples of Nawalpur Village Shahdol.

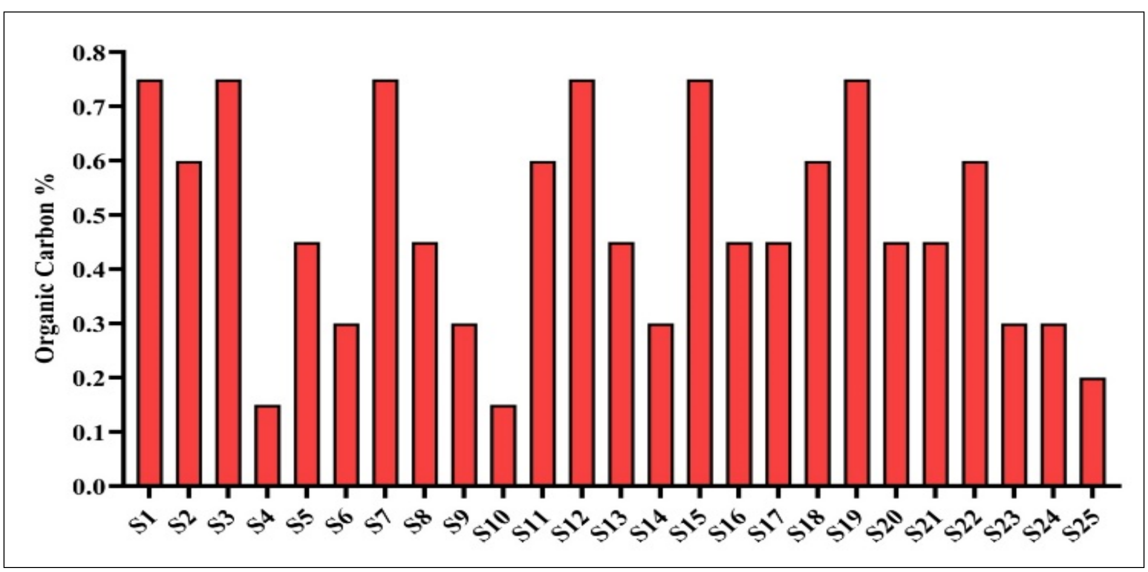

Fig 3: Organic Carbon percentages in 25 different samples of Nawalpur Village Shahdol.

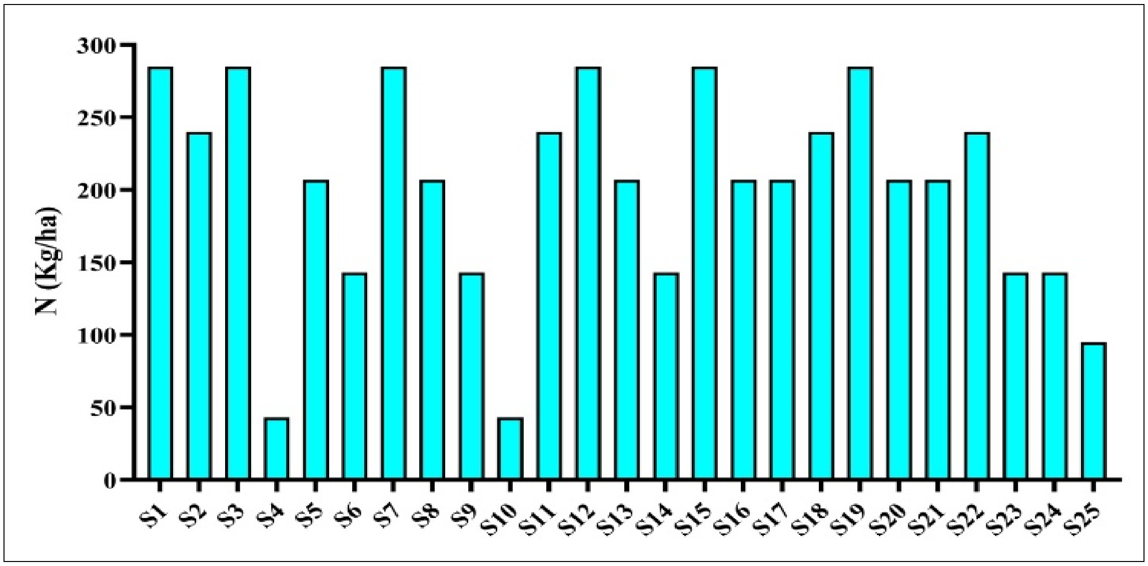

Fig 4: Macronutrient Nitrogen content in 25 different samples of Nawalpur Village Shahdol.

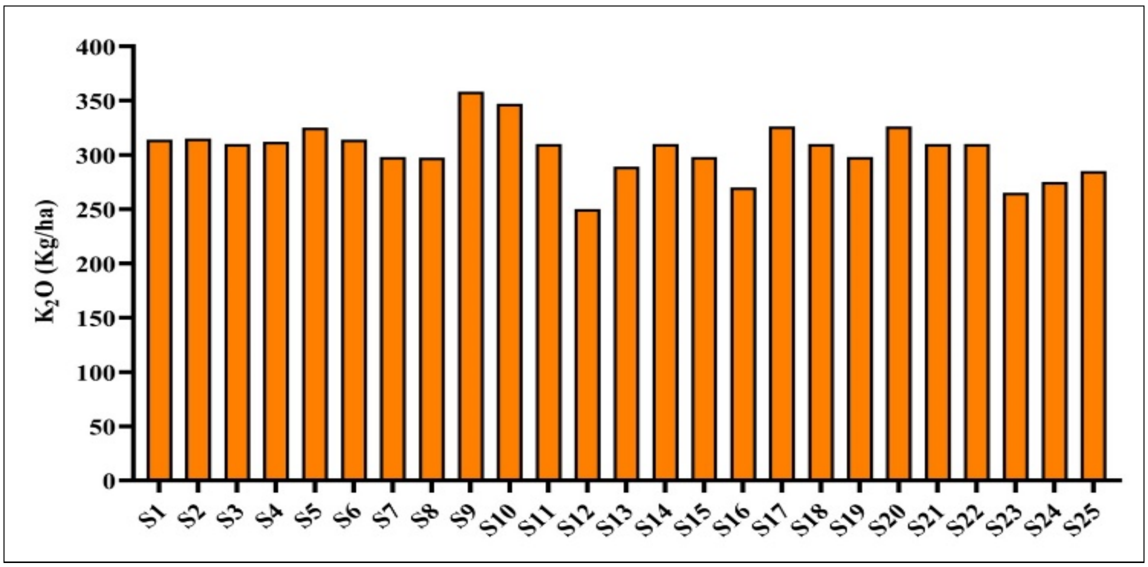

Fig 5: Macronutrient Potassium content in 25 different samples, Nawalpur Village Shahdol.

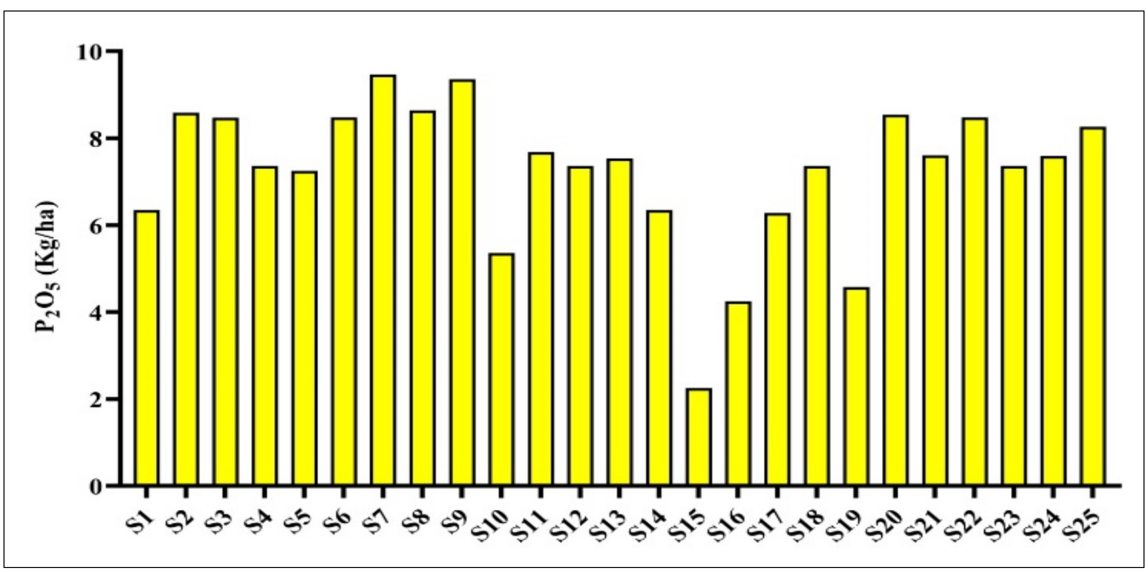

Fig 6: Macronutrient Potassium content in 25 different samples, Nawalpur Village Shahdol.

Table 1: The pH, electrical conductivity, organic carbon, nitrogen, phosphorus, and potassium content of each soil sample.

S.N.	Sample	pH	Electrical conductivity	Organic carbon	N	P_2O_2	K_2O
1	S1	6.8	0.26	0.75	285	6.35	314
2	S2	6.6	0.46	0.6	240	8.59	315
3	S3	7.4	0.17	0.75	285	8.47	310
4	S4	6.5	0.29	0.15	43	7.36	312
5	S5	7.1	0.14	0.45	207	7.25	325
6	S6	6.3	0.28	0.3	143	8.48	314
7	S7	6.8	0.26	0.75	285	9.47	298
8	S8	6.4	0.37	0.45	207	8.64	297.3
9	S9	6.9	0.38	0.3	143	9.36	358.1
10	S10	6.7	0.29	0.15	43	5.36	347
11	S11	6.6	0.46	0.6	240	7.68	310
12	S12	7.4	0.17	0.75	285	7.36	250
13	S13	7.1	0.15	0.45	207	7.54	289
14	S14	6.3	0.28	0.3	143	6.35	310
15	S15	7.3	0.36	0.75	285	2.25	298
16	S16	6.4	0.37	0.45	207	4.25	270
17	S17	6.5	0.16	0.45	207	6.28	326
18	S18	6	0.24	0.6	240	7.36	310
19	S19	7.3	0.36	0.75	285	4.58	298
20	S20	6.5	0.18	0.45	207	8.54	326
21	S21	6.9	0.36	0.45	207	7.61	310
22	S22	6.1	0.36	0.6	240	8.48	310
23	S23	6.7	0.36	0.3	143	7.36	265
24	S24	7.5	0.41	0.3	143	7.59	275
25	S25	6.8	0.3	0.2	95	8.26	285

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None

Conflicts of Interest

The authors declare no conflict of interest.

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