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# Evaluation of soil fertility condition and macro and micronutrients using biofertilizer (Azolla pinnata) at various sites in Prayagraj district, Uttar Pradesh, India

**Sarika Bajpai[1*], Krishna Narayan[2], P. P. Paroha[3]**

[1*]Pranveer Singh Institute of Technology, Department of Basic Sciences & Humanities, Kanpur-209305 U.P., India

[2.]Harcourt Butler Technical University, Kanpur, UP, India

[3.] Pranveer Singh Institute of Technology, Department of Basic Sciences & Humanities

***Corresponding author:**

Sarika Bajpai

Email ID : dr.sarikabajpai@gmail.com

## ABSTRACT

The soil of Prayagraj, Uttar Pradesh, was sampled at many locations in 2024–2025 to evaluate the macronutrients (Organic Carbon, N, P, K, Ca & Mg) and micronutrients (Zn, Fe, Mn, Cu & Co). Determine the availability of macro and micronutrients in the soil of these soil samples, perform chemical analysis of the soil at different depths of different locations, and present the village with a Soil Health Card were the main goals of this study. 32 sampling locations from various communities were chosen for the analysis. Organic carbon spans from 0.48 to 0.89 percent, nitrogen ranges from 0.8 to 8.5%, phosphorus ranges from 0.5 to 4.8%, and potassium ranges from 1.8 to 9.6%, according to the research. The pH range is 7.01 to 7.89. The levels of calcium and magnesium in soil range from 3.9 to 15.8% and 2.8 to 9.8%, respectively, and are adequate. Biofertilizer regulates the high concentration of heavy metals (Zn, Fe, Cr, and Pb) at different locations. The current study encourages the use of Azolla pinnata as a biofertilizer and illustrates the risks that heavy metals pose to human health and plants. This sustainable substitute enhances soil fertility, fertility status, and footprint while reducing issues related to heavy metal toxicity

***KEY WORDS:*** *Soil macro-micro nutrients, Bio-fertilizer, pH, Organic Carbon, Nitrogen, phosphorus, potassium, soil fertility.*

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## 1. INTRODUCTION

### 1.1 Role of macro & micro nutrients

An almost non-renewable (extremely slow rate of creation) natural resource, soil plays a vital role in both agriculture and the environment. It is the dynamic connection between the biosphere and lithosphere [1]. Because of the extensive use of soils in agriculture, it is crucial to investigate how the elemental composition varies because of both natural and man-made influences [2]. The mineral-organic carbon/soil organic matter interaction and environmental factors influenced the environmental behaviors of heavy metals [3]. Soil contamination by heavy metals (HM) poses a major safety danger to the world's rice industry. The main human-caused causes of heavy metal contamination are mining, agriculture, and industry [4]. The pH of the soil is a crucial factor in crop yield.

Plant development is influenced by the physical, chemical, and biological characteristics of the soil as well as its pH. Plants require the micronutrients Fe, Zn, Cu, and Cr to develop healthily [5]. The quality of soil components, water availability chemistry, crop nutrient delivery, and climate are the most critical factors for improved crop output [7]. Micronutrients (Fe, Zn, Cu, Mn, and B) are required in lesser proportions, whereas macronutrients (N, P, K, and CORG) are required in greater quantities [8].

### 1.2 Role & Application of Azolla pinnata on heavy metals

Free-floating ferns like Azolla pinnata are frequently employed in rice paddies as dual crops or as green manure. Nitrogen fixation raises rice yield when the dried inoculum is immersed in superphosphate solution prior to inoculation [8]. A. pinnata efficiently breaks down in soil as a rice biofertilizer, releasing nitrogen into the soil [9]. Rice or other crops are preferred for dual cropping or green manuring because of its symbiotic relationship with blue-green algae, which improves the soil. A. pinnata, also called feathery mosquito ferns or water velvet, thrives in a variety of water conditions and doubles its biomass every two to three days thanks to its blue-green algae symbiont, which stabilizes nitrogen more quickly than legumes and encourages soil microbes [10], [11].

## 2. METHODOLOGY

### 2.1 STUDY SITES –

The Prayagraj district is 98 meters above sea level and situated at 25° 26' N / 81° 50' E. From July 2024 to April 2025, soil samples were taken at regular intervals of three months from each of the eight blocks (four villages per block) in the Prayagraj district. Several sample locations are shown in Figure 1.


1) Sadar (Bajupur, Damupur, Gopalpur, Janka)

2) Bara (Akoria, Benipur, Devaria, Jasra)

3) Handia (Ahiri, Balipur, Dhanupur, Pratappur)

4) Soraon (Holagarh, Kashipur, Kasari, Mauaima)

5) Karchhana (Amba, Barauli, Chaka, Dandi)

6) Meja (Uruwa, Manda, Tikri, Sonai)

7) Koraon (Mahuli, Semri, Rajpur, Newari)

8) Phulpur (Bahariya, Bahadurpur, Devkali, Hemapur)

The study was conducted at different locations within Prayagraj district during three seasons, from July 2023 to April 2024. Soil and water samples were collected from the 8 blocks every three months. The cultivated sampling sites comprised 32 sites from which samples were taken. After being gathered, the samples were placed in polythene bags and brought to the lab to be spread out on thick brown paper and allowed to air. It is possible to remove large debris, coarse shards, stones, pieces of roots, leaves, and other particles that have not completely broken down. Disturbingly, large chunks of wet earth were shattered by hand. After that, the following preliminary procedure was applied to the samples that were collected;

Before being carefully crushed using a pestle and mortar and run through a 2-mm screen, the soil samples were allowed to air dry for 24 hours. Since practically all the minerals that are important for nutrition are present in the soil that passes through this mesh, this size has been adopted as the global standard. A pH meter was used to measure the soil's pH. The provided techniques were used to estimate nutrients.

1) Organic carbon - Walkley & Black Method [12]

2) Total Nitrogen - Kjeldahl method [12]

3) Phosphorous– Olsen method [13]

4) Potassium - Flame photometric Method [12]

5) Calcium - EDTA Titration method [12]

6) Magnesium - EDTA Titration method [12]

Soil samples were prepared for micronutrient analysis. Each 0.5 g sample was placed in Kjeldahl flasks containing HCl, $HNO_3$, and $H_2SO_4$ acids and heated slowly to digest for 10-15 minutes after white fumes appeared. To evaluate Pb, Cr, Zn, Fe, Cu, Mn, and B, the samples were chilled and diluted. To dilute them, the solutions were moved into 50 ml volumetric flasks. Using established techniques, atomic absorption spectroscopy (AAS) was used to assess heavy metals. As a quality control measure, blank samples were examined using an atomic absorption spectrophotometer.

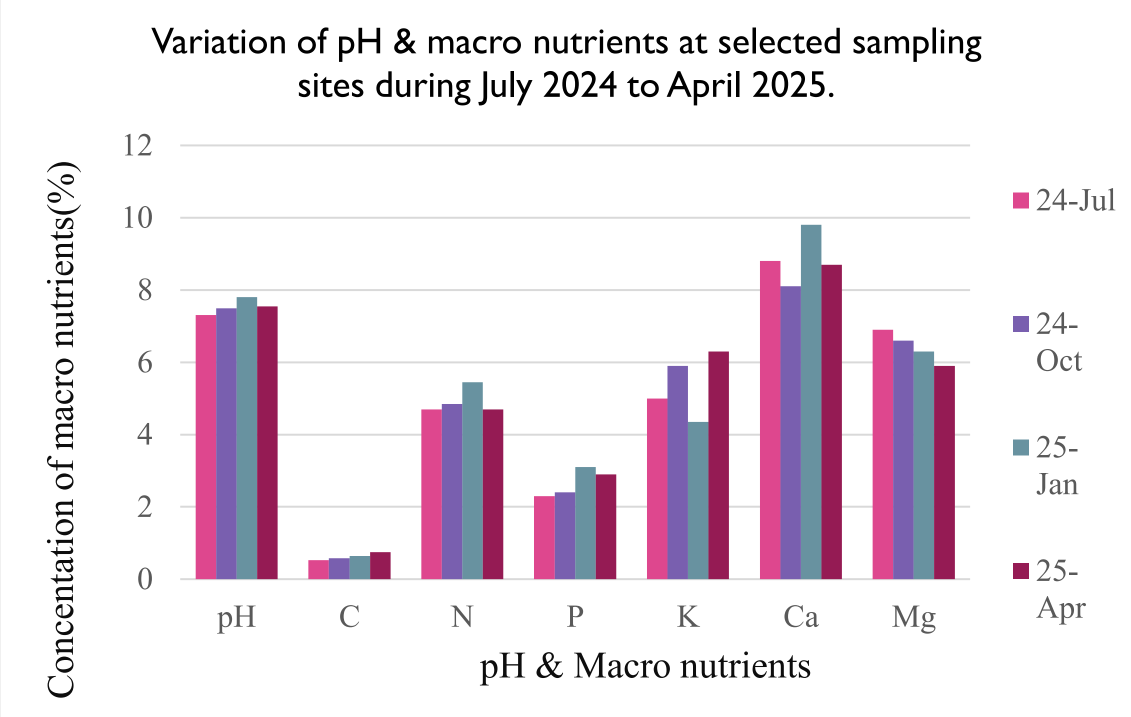
## 3. RESULT & DISCUSSION

The pH range in the current study was 7.01 to 7.89. The amount of organic carbon varied significantly, peaking in April and falling in July. While phosphorus ranged from 0.5% to 4.8%, total nitrogen ranged from 0.8% to 8.5%. All seasons had excess potassium (1.8–9.8%). All seasons also showed elevated amounts of calcium and magnesium. Table 1 and Figure 2 show the seasonal change of pH and macronutrients in soil samples taken at specific sampling locations between July 2024 and April 2025.

**Table 1: Changes in macronutrients and pH at specific sample locations from July 2024 to April 2025.**

| S.No | Parameters | Jul-24 | Mean | Oct-24 | Mean | Jan-25 | Mean | Apr-25 | Mean |
|---|---|---|---|---|---|---|---|---|---|
| 1 | **pH** | 7.01 ± 7.62 | 7.31 | 7.42 ± 7.56 | 7.49 | 7.71 ± 7.89 | 7.80 | 7.32 ± 7.78 | 7.55 |
| 2 | **Organic Carbon (%)** | 0.48 ± 0.59 | 0.53 | 0.49 ± 0.67 | 0.58 | 0.58 ± 0.71 | 0.64 | 0.62 ± 0.89 | 0.75 |
| 3 | **Total Nitrogen (%)** | 0.8 ± 3.9 | 4.7 | 2.8 ± 6.9 | 4.85 | 4.4 ± 6.5 | 5.45 | 0.9 ± 8.5 | 4.7 |
| 4 | **Phosphorous (%)** | 0.7 ± 3.9 | 2.3 | 0.5 ± 4.3 | 2.4 | 1.4 ± 4.8 | 3.1 | 1.9 ± 3.9 | 2.9 |
| 5 | **Calcium (%)** | 5.4 ± 12.3 | 8.8 | 4.8 ± 11.5 | 8.1 | 3.9 ± 15.8 | 9.8 | 6.7 ± 10.7 | 8.7 |
| 6 | **Magnesium (%)** | 4.2 ± 9.7 | 6.9 | 3.9 ± 9.3 | 6.6 | 2.8 ± 9.8 | 6.3 | 2.9 ± 8.9 | 5.9 |
| 7 | **Potassium (%)** | 2.1 ± 7.9 | 5.0 | 2.0 ± 9.8 | 5.9 | 1.8 ± 6.9 | 4.35 | 1.9 ± 8.8 | 6.3 |

**Fig. 2- Changes in macronutrients and pH at specific sample locations from July 2024 to April 2025.**




Without the use of Azolla, Zn peaked at 9.9 ppm in Apr-25 and decreased to 3.5 ppm in Jan-25 2024. Fe ranged from an extremely high value of 135.2 ppm in Apr-24 to 79.1 ppm in Jul-24 with Azolla. The manganese content varied from 75.5 ppm without Azolla in Apr-25 to 18.9 ppm in Oct-24 with Azolla. Copper fluctuated from 9.2 ppm without Azolla in Jul-24 to 3.4 ppm in Jan-25 with Azolla. Boron levels ranged from 10.8 ppm without Azolla in Oct-24 to 2.5 ppm in Jan-25 with Azolla. In the absence of Azolla, Pb peaked at 4.9 ppm in Oct-24 but decreased to 1.2 ppm in the presence of Azolla in Jul-24. Chromium ranged from a very high 68.9 ppm without Azolla in Oct-24 to 25.6 ppm with Azolla in Jan-25. The extractable levels of zinc, iron, copper, manganese, and boron below 1.2, 8.0, 0.4, 4.0, and 0.5 ppm, respectively, were considered deficient [12].

**Table 2: Variation of Micro nutrients (Heavy metals) without & with Azolla in selected sampling sites during July 2024 to April 2025.**

| Month | Block | Element | Concentration heavy metals (ppm) | |
|---|---|---|---|---|
| | | | With out Azolla | With Azolla |
| Jul-24 | Handia | Zn | 8.2 | 5.2 |
| | Meja | Fe | 112.8 | 79.1 |
| | Soraon | Mn | 75.3 | 45.3 |
| | Phulpur | Cu | 9.2 | 5.2 |
| | Koraon | B | 4.8 | 3.5 |
| | Bara | Pb | 2.9 | 1.2 |
| | Karchhana | Cr | 58.3 | 28.9 |
| Oct-24 | Handia | Zn | 5.7 | 3.4 |
| | Meja | Fe | 125.3 | 83.0 |
| | Soraon | Mn | 35.9 | 18.9 |

| | | | | |
|---|---|---|---|---|
| | Phulpur | Cu | 6.3 | 4.1 |
| | Soraon | B | 10.8 | 6.4 |
| | Bara | Pb | 4.9 | 3.9 |
| | Karchhana | Cr | 68.9 | 46.2 |
| Jan-25 | Karchhana | Zn | 9.5 | 3.5 |
| | Meja | Fe | 127.8 | 98.1 |
| | Soraon | Mn | 65.2 | 40.5 |
| | Phulpur | Cu | 6.9 | 3.4 |
| | Soraon | B | 8.5 | 2.5 |
| | Bara | Pb | 3.9 | 2.7 |
| | Karchhana | Cr | 65.7 | 25.6 |
| Apr-25 | Handia | Zn | 9.9 | 6.6 |
| | Phulpur | Fe | 135.2 | 85.1 |
| | Soraon | Mn | 75.5 | 53.1 |
| | Phulpur | Cu | 5.8 | 4.2 |
| | Koraon | B | 3.9 | 2.8 |
| | Handia | Pb | 4.8 | 2.1 |
| | Karchhana | Cr | 56.9 | 36.5 |

**Fig. 3 - Variation of micro nutrients without Azolla in selected sites during July 2024 to April 2025**

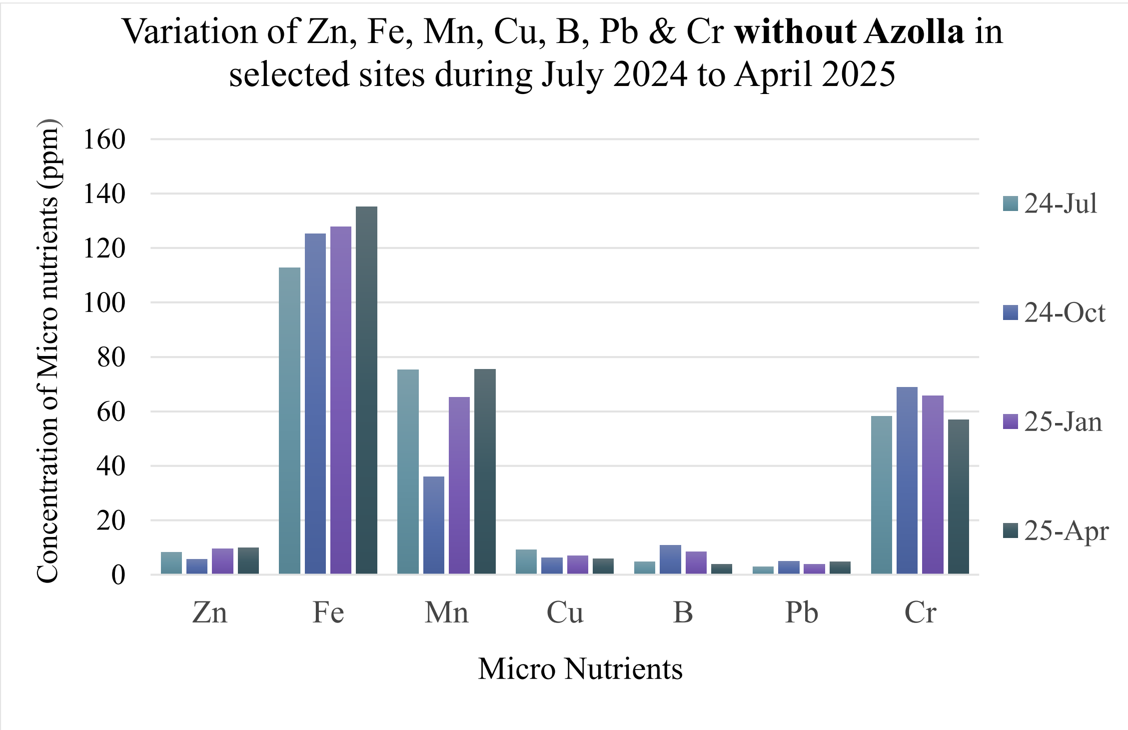
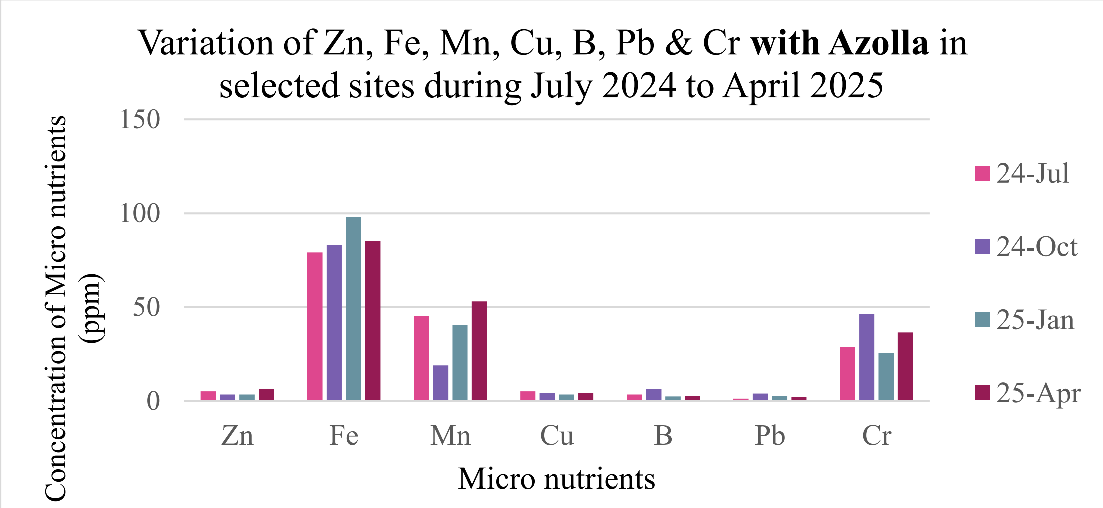


**Fig. 4 - Variation of micro nutrients with Azolla in selected sites during July 2024 to April 2025**




Tables 1 and 2 provide the physicochemical values that were acquired. It was also discovered that the soil's pH varied from little below 7.01 to 7.89 over the year, indicating a minor alkalinity. Concentrations of less than 1.2, 8.0, 0.4, 4.0, and 0.5 parts per million of zinc, iron, copper, manganese, and boron, respectively, were considered inadequate. The pH directly regulates the fluctuation in metal concentrations and has a substantial impact on the mobility and transformation of heavy metals in soil [14]. Biologically Available The soil and humans, animals, and plants are the most vulnerable to the harmful effects of heavy metals [15]. Lead levels, however, were comparatively greater at certain research locations. The environment and specialized processes, such as selective adsorption to solid phases, precipitation of soluble or stable chemicals and formation complexes, and chelation with soil organic matter, are all influenced by soil leaders [16]. One of the most prevalent metals in organic waste products, zinc functions as a micronutrient for plants but, depending on pH and organic carbon, can be hazardous to humans and plants at high quantities [17].

This increase in Cu levels can be accounted for by the formation of insoluble Cu complexes that fix the excess. The tissue concentration of Mn was high throughout the year owing to the fixation of MnO2, MnSO4, and Mn2O3% pyrolite. Fixed boron borates of Ca and Mg were sufficient.

Soil samples showed deficiency of organic carbon levels ranging across seasons. The pH leads to acid group dissociation, which increases organic carbon dissolution. Nitrogen concentrations can increase with urea and sodium, potassium, and calcium nitrates. Phosphorus content varied low to medium levels. Approximately 40% of the soils had low to medium available potassium, with potassium deficiency increasing with intensive cropping and imbalanced fertilizer use [18]. The phosphorous concentration increased with increasing pH. The fixation of soluble salts at high temperatures is the cause of the high potassium concentration. Medium potassium and low nitrogen were found in alkaline soils.

## 4. CONCLUSION

For the Prayagraj district, the big picture showcased that the soil is of alkaline nature. High iron was reported all year. Copper was also high at all the sites; excess could be probably due to chemical fertilizers forming insoluble copper complexes. Predominantly high concentration of manganese and chromium were noted in all the seasons. Boron had the right amount of concentration all the months but had too much of it in October. Organic carbon was found to be positively correlated with total nitrogen content of the soil. Additional contributions of carbon included stabilized mineral carbon and excessive cropping have also contributed to carbon accumulation as organic matter. There was also a rich positive relationship revealed with phosphorus concentration rising as pH levels went up. Soluble salts fix at high temperatures and potassium was high in July. Chemical fertilizers entail high levels of heavy metals which are poisonous to plants and humans, the level should be reduced by using microbial/bio- Azolla pinnata instead of chemical fertilizers. There is another saying in agriculture that best nutrient level and moisture enhance the production of crops. Macronutrients should be balanced properly by applying the right salts and avoiding leaching of these nutrients in to the ground water.

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