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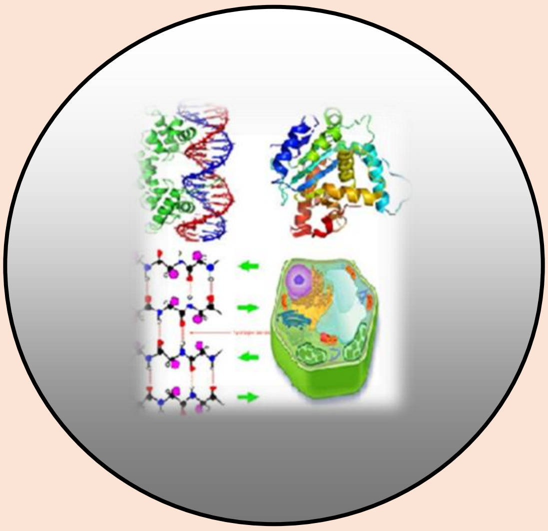

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# Exploring the Soil Fertility and Plant Productivity in Different Areas in District Barabanki, Uttar Pradesh, India

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## ABSTRACT

*Soil is the basic medium for plant growth, as it provides all the essential minerals during various stages of plant development. At the dawn of civilization, most agricultural activity was carried on in the fertile soils of rivers. The rapid increase in population exacerbated the problem of soil pollution to meet the food needs of overpopulation. At the same time, the quality of soils continued to deteriorate due to the improper use of inorganic fertilizers. Declining soil fertility has become a threat to agricultural productivity and agrarian scenario. The study was conducted to investigate soil fertility and crop productivity in four blocks of Barabanki district where rice has been cultivated for many years. Declining soil fertility has adversely affected rice crop productivity. The most important components of soil are nitrogen, phosphorus, and potassium, which are essential for productivity, followed by soil pH and carbon content. Therefore, the availability of these components and the management of soil nutrients and organic manure are essential for the sustainability of agricultural productivity. We concluded that soil fertility and crop productivity are slightly different in different areas of Barabanki district, Uttar Pradesh, India. The soil fertility and crop productivity were lowest in the Banke block in comparison to the other three blocks. The Fatehpur and Nindura block areas were reached in phosphorus and potassium. Although Nitrogen and organic matter were more in the Dewa block area.*

*Keywords: Soil fertility, Plant productivity, Cultivation and Paddy Crop.*

## INTRODUCTION

The productive capacity of the soil is represented by soil fertility, which also ensures crop yields and is the basis for sustainable agriculture. One of the most important factors in determining soil fertility is the growth and production status of plants [Abdu et al., 2022].

Theoretical support and technical assistance for sustainable agricultural production and management can be provided by limited indicator analysis of soil quality. Soil fertility assessment and limiting indicator analysis should be carried out to fully and comprehensively study soil fertility from the production point of view [Vidal Legaz et al., 2017]. Soil is primarily used in agriculture or engineering, and this bias is reflected in soil classifications, categorization schemes, and research. According to Brady (1974), the soil is "a dynamic natural body on the earth's surface on which plants grow and which is composed of minerals, organic matter, and living forms" [Brady and Buckman, 1974]. Soil is a natural material that can be used as a soil resource. Human intervention in the earth's ecosystem to produce food and fiber creates a greater need for soils to provide the necessary nutrients [Nunes et al., 2020].

Continuous cultivation to increase yields removes significant amounts of nutrients from the soil. Unbalanced and inappropriate use of chemical fertilizers, improper irrigation, and various cultural practices also lead to rapid soil degradation [Salve, 2012]. Anthropogenic factors such as inappropriate land use systems, monocultures, nutrient depletion, and inadequate nutrient supply aggravate the situation [Majumdar et al., 2016].

In India, low soil fertility is the main obstacle to achieving high productivity goals. Soil fertility fluctuates over the growing season as the amount and availability of mineral nutrients change due to the addition of fertilizers, manure, compost, mulch, and lime, and leaching [Bhattacharyya et al., 2015, Dhaliwal et al., 2019]. Available nutrients in intensively managed soils, especially secondary and micronutrients, are depleted. Before the advent of artificial fertilizers, manure was the main source of nutrients for crop production. Nutrient inputs from fertilizers and farm manures lag well behind crop removals in both agriculturally highly developed irrigated ecosystems and less well-supplied rainfed areas, resulting in years of nutrient stock depletion [Chandini et al., 2019]. Widespread deficiencies of N, P, K, S, Zn, Fe, B, etc. have been observed and significant plant responses to the supply of these nutrients have been reported. The deficiency symptoms are so pronounced and severe that visible symptoms are very common in important crops [Jones et al., 2013].

The most populous state in India, Uttar Pradesh is often referred to as the "heartland of India" and is home to nearly one-sixth of the country's population. Uttar Pradesh has a tropical monsoon climate with mild temperatures year-round. In Lucknow, the capital of Uttar Pradesh, maximum temperatures vary from about 20 °C in January to over 38 °C in May and June. There are reports of maximum temperatures of 50 °C (120 °F), and annual rainfall varies from 600 to 1,000 mm (24 to 40 inches) in the west and 1,000 to 2,000 mm (40 to 80 inches) in the east of the country. The southwest monsoon, which lasts from about June to September, brings about 90% of the rainfall. Flooding is a constant problem that can cause deaths and significant damage to agriculture and property, especially in the eastern half of the state, as most of the rainfall is concentrated during these four months. Drought is caused by the occasional failure of the monsoon to arrive. Barabanki district is located about 20 km east of Lucknow, and the district's economy is mainly based on agriculture. The geographical area of Barabanki is ~ 3891.5 square kilometers. In Barabanki, the net irrigated area is 84.2% compared to 79.0% in U.P. Compared to U.P., Barabanki has 176.9% higher irrigation intensity than this state. Irrigation opportunities in Barabanki district are better than the state average. In Barabanki, private tube wells and canals account for 69.0 and 29.9 percent of the irrigation system, respectively, compared to 87.9 and 20.9 percent in U.P.

In Barabanki, irrigation from state tube wells and other sources - such as ponds and rivers - is significantly lower than in the state as a whole. Farmers in Barabanki County practice subsistence agriculture. Annually, farmers may grow up to five different crops in rotation. Cereals, mainly rice and wheat, account for the largest share of gross cropped area, 34.4% and 31.3%, respectively, while in the state of Uttar Pradesh, these shares are 23.1% and 40.6%, respectively [Economy | District Barabanki GoUPhbnia-de]. Therefore, assessing the fertility status of the soils of an area or region is an important aspect related to sustainable agriculture [Ramana et al., 2016]. For the present study, the following objectives were set by the Barabanki region. The objective was to understand the physicochemical nature of the soil, how nutrients (NPK) affect yield, and how soil fertility affects sustainable and profitable production, taking into account the aforementioned objectives.

**Sample Collection**

Soil samples were collected from different blocks of Barabanki district- Banki, Dewa, Fatehpur, and Nindura. The four villages Ganaura, Tindola, Bibipur, and Padri represented the four blocks, respectively.

## MATERIALS AND METHODS

Soil samples were collected before sowing and after harvesting in each replicate from 0-15, 15-30, and 30-60 cm soil depth using an auger. Bulk density was determined by storing the soil samples in an oven at 105 °C for 48 hours and expressing them in g/cc [Dastane NG:6 Oct 2008].

$$\text{Bulk density (g/cc)} = \frac{\text{Weight of oven dried soil}}{\text{Volume of wet soil}}$$

The weight per unit volume of the solid portion of the soil is called the particle density.

**Chemical Properties of Soil**

Soil pH was measured in a 1:2.5 soil-water suspension by potentiometry. Weigh 20 g of air-dry soil through a 2 mm sieve and place it in a clean 100 ml beaker. Add 50 ml of distilled water (1:25 ratio). Stir the contents with a glass rod and allow to stand for 30 minutes with constant stirring. Carefully wash the electrode with a stream of distilled water and wipe it with a piece of filter paper. Stir the soil suspension again just before taking the reading. Measure the temperature of the soil water suspension and set the temperature compensation knob to the temperature of the suspension. Immerse the electrode in the beaker containing the soil water suspension and set the function switch to the respective pH range. Record the reading in both the supernatant solution and the suspension. Rinse the electrode with a stream of distilled water and immerse it in distilled water. The clear supernatant solution of the soil-water suspension was taken and the electrical conductivity was measured using the conductivity bridge [Chatli et al., 2016]. Turn on the meter EC and wait 15 minutes for it to warm up. Standardize the meter with saturated gypsum solution or 0.01 M KCl solutions. The EC of saturated gypsum and KCl solution should be 2.2 and 1.41 dS m-1, respectively.

Use the same soil water suspension for the determination of EC as for the pH measurement. Stir the contents and allow the soil to settle. Wash the electrodes carefully and immerse them in the soil solution. Measure the temperature of the suspension and adjust the temperature correction knob to the temperature of the suspension. Read the EC directly on the meter display in dS m-1.

**Organic Carbon**

Organic carbon was determined by the wet oxidation method of Walkley and Black by oxidation of organic material as described by (Walkley and Black, 1934) [Poudel, 2020]. It was expressed as a percentage. About 5 g of the 2 mm sieved soil sample was finely pulverized with a ceramic pestle and mortar and sieved through a 0.2 mm sieve, leaving no residue on the sieve. Weigh 0.5 g of the soil sample into a dry 500 ml conical flask. At the same time, perform a blank test without soil. add 10 ml of a 1-N potassium dichromate solution with a pipette, swirl the flask gently to completely wet the soil sample, and keep it on an asbestos plate. add 20 ml of concentrated $H_2SO_4$ briskly using a graduated cylinder or tipping pipette by passing the vapor into the suspension. Shake the contents of the flask for 2 to 3 minutes and leave it on the asbestos plate for 30 minutes. Add approximately 200 ml of distilled water to the flask. add 10 ml of ortho-phosphoric acid and 1 ml of diphenylamine indicator. Titrate the contents against 0.5 N FAS until a green color appears.

**Available Nitrogen**

Available nitrogen was estimated by the alkaline permanganate oxidation method according to (Subbiah and Asija, 1956) [Rajani, 2019, Subbiah, 1956]. It was expressed in kg ha-1. 20 g of a 2 mm sieved soil sample is weighed and placed in a distilled nitrogen flask. add 20 ml of distilled water, 1 ml of liquid kerosene (or 1 g of kerosene wax) (to avoid foaming), and some glass beads/porcelain pieces (to avoid impact) to the distillation flask. add 100 ml of 0.32-percent potassium permanganate. Pipette 20 ml of a 2 percent boric acid solution with double indicator into a 250 ml beaker. Hold the beaker under the outlet end of the condenser so that the outlet end is immersed in the acid. This will trap some of the ammonia released during the initial stage of distillation as a gas. Open the top water port of the condenser. Add 100 ml of 2.5% sodium hydroxide to the distillation flask. Immediately close the flask and distill the contents of the flask at a steady rate, collecting the distillate in the 100 ml beaker. After a few seconds (when the bubbling in the beaker stops), lower the beaker below the level of the collection tube. This prevents the distillate from being sucked back into the distillation flask. Continue distillation for approximately 30 minutes or until 100 ml of distillate is in the beaker. Titrate the collected ammonia with 0.02 N $H_2SO_4$ until a wine red color is obtained. From the titer value, calculate the amount of nitrogen present in the soil.

**Available Potassium**

The available potassium was extracted with neutral normal ammonium acetate (1 N $NH_4OAC$) and the K content in the solution was estimated by flame photometry Ashokkumar V. Rajani et. al [2019]. It was expressed in kg ha-1. Weigh 5 g of soil into a 100-mL polyethylene shaker bottle. Perform a side-by-side blank sample without soil. Add 25 mL of neutral normal ammonium acetate (N N $NH_4OAc$) and shake for 5 minutes in a mechanical shaker at 180 rpm. Filter through No. 40 Whatman filter paper and collect the filtrate in a 50-mL beaker. Turn on the air compressor and set the air pressure according to the instructions in the instrument.

Turn on the flame photometer and allow it to warm up for 30 minutes. Open the LP gas and light the burner. Set the burner knob to a flame with blue cones. Pour in N N $NH_4OAc$ and adjust the zero control knob to show zero on the digital display. Add 100 ppm K solution and adjust the standard curve so that 100 is shown on the digital display. Add the other K standards and establish the standard curve. Add the sample and determine the K concentration of the sample using the standard curve.

**Available Phosphorus**

When testing phosphorus in the soil, the Olsen method (Olsen et al., 1954) is generally used to extract available phosphorus from the soil [Olsen and Sommers, 1982].

**Determination of Moisture Content**

Record the weight of a container (beaker or Petri dish) and label it. Weigh 10 g of the soil sample and record the total weight of the sample and container. Dry the samples in an oven at 105 °C for 48 hours. Record the weight of the container + the sample. Record the dry weight of the soil sample (by subtracting the total weight from the container weight). Calculate the moisture content and dry weight of the soil using the following formula.

$$\text{Moisture percentage} = \frac{\text{Wet weight (g)} - \text{Dry weight (g)}}{\text{Wet Weight (g)}} \times 100$$

**Table 1. Chemical properties of soil in different location before sowing of paddy crop.**

| Block | Village | Nitrogen (kg/hectare) | Phosphorus (kg/hectare) | Potassium (kg/hectare) | pH | Organic matter (%) |
|---|---|---|---|---|---|---|
| Banki | Ganaura | 237 | 8.0 | 224 | 6.9 | 1.3 |
| Dewa | Tindola | 242 | 5.0 | 221 | 7.0 | 1.8 |
| Fatehpur | Bibipur | 223 | 6.0 | 236 | 7.1 | 1.2 |
| Nindura | Padri | 220 | 10.0 | 246 | 6.9 | 1.2 |

**Table 2. Analysis of morphological parameters of paddy plants at the harvesting stage.**

| Block | Plant height (cm) | Number of leaves/plant (cm) | Length of root/plant(cm) | No. of tillage | Fresh wt. (g) | Dry wt. (g) | Yield (g)/grains dry wt. (g) |
|---|---|---|---|---|---|---|---|
| Banki | 105.8 | 13.80 | 26.6 | 18.2 | 183.2 | 19.2 | 26.5 |
| Dewa | 106.2 | 13.10 | 27.2 | 16.5 | 185.3 | 18.3 | 25.3 |
| Fatehpur | 105.6 | 12.40 | 24.5 | 18.6 | 186.7 | 20.4 | 27.2 |
| Nindura | 105.3 | 12.20 | 25.9 | 15.9 | 180.5 | 19.8 | 26.9 |

## RESULTS

Table 3 shows the chemical properties of the soil at different locations before sowing the paddy crop. Nitrogen (kg/hectare), phosphorus (kg/hectare), potassium (kg/hectare), pH, organic matter (%), Fe (mg/kg), Zn (mg/kg) and S (mg/kg) were 237, 8.0, 224, 6.9, 1.3, 36, 1.4 and 11 in Ganaura village in Banki block, 242, 5.0, 221, 7.0, 1.8, 37, 1.2 and 11 in

Tindola village of Dewa block, 223, 6.0, 236, 7.1, 1.2, 35, 1.2 and 15 in Bibipur village of Fatehpur block and 220, 10.0, 246, 6.9, 1.2, 34, 1.2 and 12 in Padri village of Nindura block of Barabanki before sowing of paddy crop.

**Table 3. Chemical properties of soil in different locations before sowing of paddy crop.**

| Chemical properties of soil | Different locations in Barabanki | | | |
|---|---|---|---|---|
| | Ganaura, Banki | Tindola, Dewa | Bibipur, Fatehpur | Padri, Nindura |
| Nitrogen (kg/hectare) | 237 | 242 | 223 | 220 |
| Phosphorus (kg/hectare) | 8 | 5 | 6 | 10 |
| Potassium (kg/hectare) | 224 | 221 | 236 | 246 |
| pH | 6.9 | 7 | 7.1 | 6.9 |
| Organic matter (%) | 1.3 | 1.8 | 1.2 | 1.2 |
| Fe (mg/kg) | 36 | 37 | 35 | 34 |
| Zn (mg/kg) | 1.4 | 1.2 | 1.2 | 1.2 |
| S (mg/kg) | 11 | 11 | 15 | 12 |

Table 4 shows the photosynthetic pigments in 95-day-old rice (Oryza sativa cv.Sarju-52). Photosynthetic pigments chlorophyll a, chlorophyll b, total chlorophyll, total carotenoid, pheophytin a, pheophytin b and total pheophytin (mg/g fresh weight) were 1.367, 0.487, 1.977, 0.603, 1.787, 0.858 and 2.645 in Ganaura village in Banki block, 2.557, 0.907, 3.560, 0.783, 3.920, 1.590 and 4.88 in Tindola village in Dewa block, 2.365, 1.301, 3.551, 0.677, 3.053, 1.815, 4.868 in Bibipur village in Fatehpur block and 2.550, 0.900, 3.550, 0.773, 3.280, 1.580 and 4.87 in Padri village in Nindura block of Barabanki in 95 days old rice (Oryza sativa cv.Sarju-52).

**Table 4. Photosynthesis pigments in 95 days old Rice (*Oryza sativa* cv. Sarju-52).**

| Block | Chlorophyll "a" (mg/g fresh wt.) | Chlorophyll "b" (mg/g fresh wt.) | Total Chlorophyll (mg/g fresh wt.) | Total Carotenoid (mg/g fresh wt.) | Pheophytin "a" (mg/g fresh wt.) | Pheophytin "b" (mg/g fresh wt.) | Total Pheophytin (mg/g fresh wt.) |
|---|---|---|---|---|---|---|---|
| Banki | 1.367 | 0.487 | 1.977 | 0.603 | 1.787 | 0.858 | 2.645 |
| Dewa | 2.557 | 0.907 | 3.56 | 0.783 | 3.92 | 1.59 | 4.88 |
| Fatehpur | 2.365 | 1.301 | 3.551 | 0.677 | 3.053 | 1.815 | 4.868 |
| Nindura | 2.55 | 0.9 | 3.55 | 0.773 | 3.28 | 1.58 | 4.87 |

Table 5. shows the morphological parameters of paddy plants at the harvest stage. The morphological parameters such as plant height (cm), number of leaves/plant (cm), length of root/plant (cm), number of tillage, fresh weight (g), dry weight (g), and yield (g)/dry weight of grains (g) were 105.8, 13.8, 26.6, 18.2, 183.2, 19.2 and 26.5 at Ganaura village in Banki block; 106.2, 13.1, 27.2, 16.5, 185.3, 18.3 and 25.3 at Tindola village in Dewa block; 105.6, 12.4, 24.5, 18.6, 186.7, 20.4 and 27.2 at Bibipur village in Fatehpur block; and 105.3, 12.2, 25.9, 15.9, 180.5, 19.8 and 26.9 at Padri village in Nindura block of Barabanki from paddy plants at harvest stage.

**Table 5. Analysis of morphological parameters of paddy plants at the harvesting stage.**

| Block | Plant height (cm) | Number of leaves/plant (cm) | Length of root/plant(cm) | No. of tillage | Fresh wt. (g) | Dry wt. (g) | Yield (g)/grains dry wt. (g) |
|---|---|---|---|---|---|---|---|
| Banki | 105.8 | 13.8 | 26.6 | 18.2 | 183.2 | 19.2 | 26.5 |
| Dewa | 106.2 | 13.1 | 27.2 | 16.5 | 185.3 | 18.3 | 25.3 |
| Fatehpur | 105.6 | 12.4 | 24.5 | 18.6 | 186.7 | 20.4 | 27.2 |
| Nindura | 105.3 | 12.2 | 25.9 | 15.9 | 180.5 | 19.8 | 26.9 |

To explore the effect of Zn, Fe, and S on rice plants, a pot experiment was conducted in Lucknow University wirehouse in Botany Department. Table 6 shows the effects of nutrients on germination and growth in 120-day-old rice plants. Germination (%), plant height (cm), number of shoots/plant, fresh weight/plant (gm), dry weight/plant (gm), and grain weight/plant (gm) were 94.01, 95.9, 11.8, 171.3, 15.8 and 22.4 in the control group, respectively. The normal and excess effects of nutrients Zn, Fe, and S on germination (%), plant height (cm), the number of shoots/plant, fresh weight/plant (gm), dry weight/plant (gm), and grain weight/plant (gm) were slightly increased in 120-day-old rice plants compared with the control groups.

**Table 6. Effects of nutrients on seed germination and growth in 120 days old rice plants.**

| Treatment | | Germination % | Plant height (cm) | No. of tillers/ plant | Fresh weight/plant (gm) | Dry weight/ plant (gm) | Grain weight/plant (gm) |
|---|---|---|---|---|---|---|---|
| Control | | 94.01 | 95.9 | 11.8 | 171.3 | 15.8 | 22.4 |
| Zn | Deficient | 93.05 | 95.2 | 12.9 | 165.6 | 14.6 | 22.6 |
| | Normal | 94.7 | 96.6 | 11.7 | 170.2 | 15.7 | 23.7 |
| | Excess | 95.31 | 97.6 | 13.3 | 177.5 | 16.9 | 24.2 |
| Fe | Deficient | 94.6 | 95.4 | 12.5 | 175.4 | 16.9 | 24.1 |
| | Normal | 95.4 | 94.2 | 13.6 | 174.9 | 16.3 | 23.5 |
| | Excess | 96 | 98.7 | 14.2 | 179.7 | 17.6 | 26.8 |
| S | Deficient | 93.03 | 96.9 | 13.6 | 174.3 | 16.5 | 23.8 |
| | Normal | 95.21 | 96.5 | 12.7 | 172.5 | 16.1 | 23.3 |
| | Excess | 96.23 | 98.2 | 11.4 | 176.9 | 17.4 | 26.4 |

## DISCUSSION

### Available Nitrogen

The available nitrogen content was low in the blocks of Banki, Dewa, Fatehpur, and Nindura villages as 237, 242, 223 and 220 kg/h, respectively, of the analyzed samples had nitrogen content below 280 kg/h, which could be due to the low organic matter content in these soils. the available N in soils ranged from 106 to 291 kg ha-1 with a mean value of 184 kg/ha. The variations in nitrogen content may be related to soil management and the application of digestate, and fertilizers to the previous crop.

Soil nitrogen content depends on temperature, rainfall, and elevation. In addition, continuous and intensive cultivation leading to high crop erosion, together with insufficient replenishment of soils, could be the reason for the high nitrogen deficiency in these soils.

**Available Phosphorus**

The phosphorus content in the soils of the study area varied between 8.0 and 10.0 kg/ha. The mean content was significantly low in the soils of all blocks (Table 1). Phosphate ions enter the soil solution either through the mineralization of organophosphates or through fertilizer application. Plants take up available P mostly in the form of $H_2PO_4$- from the soil solution. The available P content ranged from 8 to 65 kg ha-1 with a mean of 27 kg/ha, and 1%, 36%, and 63% of the soils were classified as low, medium, and high, respectively. The majority of the studied soils fell in the medium to high range, and the value of the available P nutrient index was high. Accumulation of available P was reported to be much higher than the value for high available P (> 25 kg/ha). To take full advantage of soil P accumulation, crop P requirements need to be reevaluated and the current assessment of available P needs to be changed. Chemisorptions of P result from the interaction of phosphate ions with atoms such as aluminum (Al), iron (Fe), or calcium (Ca), depending on soil pH. A low P content in soil samples may be due to a low supply of phosphate fertilizer over a period of time.

**Available Potassium**

Potassium is present in the K+ form and its function appears to be catalytic . Potassium is important to plants because it is involved in the activation of a large number of enzymes involved in plant physiological processes. It controls water balance and provides resistance to several pests, diseases, and environmental stresses. The exchangeable K status in surface soils ranged from 145 to 358 kg/ha with a mean of 229 kg/ha. In the low, medium, and high categories, samples fell into the 00, 88, and 12% ranges, respectively. Most soil samples had medium available K content and medium nutrient index for exchangeable K. The potassium content in the soils of the study area ranges from 110-280 kg/ha. The mean content was significantly high in the soils of Nidura (246.0 kg/ha) and medium in the soils of Ganaura, Tindola, Bibipur, and Padri (224, 221, 236 kg/ha) (Table 1). The medium level of available phosphorus in the soils of Ganaura, Tindola, and Padri could be due to the low use of potassium fertilizer. In these villages, small-scale irrigation is practiced by a relatively large number of farmers. Therefore, the leaching caused by irrigation, combined with the strong acidity that does not allow the storage of potassium in the exchangeable soil complex, could be the probable reason for the low phosphorus status of these soils.

**Soil Reaction (soil pH)**

Soil pH or soil reaction is an indicator of soil acidity or alkalinity and is measured in pH units. The measurement of soil pH is an important parameter that helps to identify the chemical nature of the soil because it measures the hydrogen ion concentration in the soil, indicating the acidic or alkaline nature of the soil. Plant nutrient supply and thus soil fertility is affected by pH. The solubility of most nutrients varies as a function of pH. The study found that soil pH values in all villages were slightly acidic to neutral (6.9 –7.1). Therefore, high pH values are indicative of the development of salinity in the soils.The pH of the surface soils of Shahanshahpur village in the Araziline block of the Varanasi district ranged from 7.3 to 8.4 with a mean of 7.9 indicating the alkaline nature of the soil. Most of the soils fall under the slightly alkaline to alkaline category.

**Organic Carbon**

Organic matter plays an important role in agricultural soils. It provides plant nutrients, improves soil structure, improves water infiltration and retention, feeds soil microflora and fauna, and improves the retention and cycling of applied fertilizer [Johnston, 2007]. The organic carbon content in the soils of the study area varied from 1.2 to 1.8%. The mean value was significantly high in Ganaura, Tindola, Bibipur, and Padri (Table 1). The study revealed that the organic carbon content in the soils of the study area was significantly high. High organic matter content not only meets part of the nitrogen needs of crops but also improves the nutrient and water retention capacity of soils and creates a favorable physical, chemical, and biological environment [Kavitha, 2015]. The soils had an average organic carbon content of 5.8 g kg-1, ranging from 3 to 9 g kg-1. It was found that the organic carbon content of 33% of the soils was low, 53% was medium and 14% was high. Low utilization of crop residues and the addition of organic manure coupled with rapid decomposition and mineralization of organic matter under subtropical climatic conditions might have contributed to the deficiency of organic carbon in the soils. The results (Table 1) show that the soil samples in Ganaura, Tindola, Bibipur, and Pandri each fall into the low category (< 0.5%). Continuous and intensive cultivation resulting in high crop removal could be responsible for the low organic carbon content characteristic of the samples from these villages. Among Indian states, Uttar Pradesh burned the most crop residues (Jain et al., 2014) [Rai and Singh, 2018], which could be the main cause of low soil organic carbon content.

**Sulphur**

In this study, S content (mg/kg) before paddy sowing was 11 in Ganaura village in Banki block, 11 in Tindola village in Dewa block, 15 in Bibipur village in Fatehpur block, and 12 in Padri village in Nindura block of Barabanki. In surface soils, accessible S status ranged from 7 to 33 mg kg-1 with a mean of 15.52 mg $kg^{-1}$ [Rai and Singh, 2018]. Of the total samples, 26, 48 and 26% fell into the low, medium, and high categories, respectively. The majority of the soil samples had medium available S content, and the nutrient index for available S was also in the medium range.

**Iron (Fe)**

In this study, the Fe (mg/kg) was 36 in Ganaura village in Banki block, 37 in Tindola village of Dewa block, 35 in Bibipur village of Fatehpur block, and 34 in Padri village of Nindura block of Barabanki before sowing of paddy crop. According to Rai et al. (2018), the DTPA-extractable Fe concentration of the soils ranged from 2.9 to 16.40 mg/kg, with a mean value of 8.42 mg/kg. Although virtually all soils were found to have moderate to adequate levels of DTPA-extractable Fe, 6% of the soils had low to moderate nutrient indices.

**Zinc (Zn)**

In the present study, the Zn (mg/kg) and S (mg/kg) were 1.4 in Ganaura village in Banki block, 1.2 in Tindola village of Dewa block, 1.2 in Bibipur village of Fatehpur block and 1.2 in Padri village of Nindura block of Barabanki before sowing of paddy crop. According to Rai et al. (2018), the DTPA extractable Zn concentration in surface soils ranged from 0.38 to 3.04 mg/kg soil, with a mean value of 1.08. Here, we found that 58% of the soils had medium Zn contents (0.5 mg/kg), and the nutrient index of the accessible Zn was also placed in the medium category.

In our study, the morphological parameters such as plant height (cm), number of leaves/plant (cm), length of root/plant (cm), number of tillage, fresh weight (g), dry weight (g) and yield (g)/dry weight of grains (g) were 105.8, 13.8, 26.6, 18.2, 183.2, 19.2 and 26.5 at Ganaura village in Banki block; 106.2, 13.1, 27.2, 16.5, 185.3, 18.3 and 25.3 at Tindola village in Dewa block; 105.6, 12.4, 24.5, 18.6, 186.7, 20.4 and 27.2 at Bibipur village in Fatehpur block; and 105.3, 12.2, 25.9, 15.9, 180.5, 19.8 and 26.9 at Padri village in Nindura block of Barabanki from paddy plants at harvest stage. In this study the effects of nutrient treatment on 120-day-old rice plants in terms of germination (%), plant height (cm), number of shoots per plant, fresh weight per plant (gm), dry weight per plant (gm), and grain weight per plant (gm) (Table 4). Comparing the 120-day-old rice plants with the control groups, the normal and excess effects of nutrients Zn, Fe, and S on germination (%), plant height (cm), the number of shoots/plant, fresh weight/plant (gm), dry weight/plant (gm), and grain weight/plant (gm) were slightly increased.

## CONCLUSION

We concluded that the values of nitrogen (kg/hectare), phosphorus (kg/hectare), potassium (kg/hectare), pH, organic matter (%), Fe (mg/kg), Zn (mg/kg), and S (mg/kg) were 220-242, 5.0-8.0, 221-246, 6.9-7.1, 1.2-1.8, 34-37, 11.2-1.4 and 11-15 in different blocks of Barabanki before paddy sowing. The morphological parameters such as plant height (cm), number of leaves/plant (cm), length of roots/plant (cm), number of tillage, fresh weight (g), Dry weight (g), and yield (g)/dry weight of grains (g) were 105.3-106.2, 12.2-13.8, 24.5-27.2, 15.9-18.6, 180.5-186.7, 18.3-20.4 and 25.3-27.2 in the different blocks of Barabanki in paddy plants at harvest stage. Comparing the 120-day-old rice plants with the control groups, the normal and excess effects of nutrients Zn, Fe, and S on germination (%), plant height (cm), the number of shoots/plant, fresh weight/plant (gm), dry weight/plant (gm) and grain weight/plant (gm) were slightly increased.

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