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Study of Physico-chemical and Nutrient Status of the Soil in Chiraigaon Block, Varanasi District, Uttar Pradesh, India

Anand Kumar Diwakar [a*++], Janardan Yadav [b#], Kuldeep Patel [c++], Sunil Kumar Prajapati [d†], V. J. Vandana [b++] and Ram Lakhan Soni [e++]

[a] Soil Science-Soil and Water Conservation, Banaras Hindu University, Varanasi, Uttar Pradesh, India.
[b] Department of Soil Science and Agricultural Chemistry, Banaras Hindu University, Varanasi, Uttar Pradesh, India.
[c] Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore-03, India.
[d] Division of Agronomy, ICAR-Indian Agricultural Research Institute, New Delhi-110012, India.
[e] Department of Soil Science and Agricultural Chemistry, Nandini Nagar P. G. College, Nawabganj, Gonda, Uttar Pradesh, India.

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 the soil fertility and their quality parameters of Chiraigaon Block of Varanasi district Uttar Pradesh (U.P.) which is located at Latitude 25.3°N, and Longitude is 82.9°E and at elevation of 81m above mean sea level (AMSL) in the centre of Gangatic plain of

[++] *M.Sc. (Ag.);*
[#] *Professor;*
[†] *Ph.D. Research Scholar;*
**Corresponding author: E-mail: 97ananddiwakar97@gmail.com;*

Northern India. A total of 54 soil samples were collected from the farmland of six different villages of Chiraigaon Block. Physico-chemical property analyses showed average bulk density and particle density of 1.22 and 2.37 mg/m^3 respectively whereas water holding capacity ranged from 29.80 to 51.70 %, pH ranged from 7.1 to 8.3, EC ranged from 0.18 to 1.68 dSm^{-1} and organic carbon content ranged from 0.21 to 0.76 % with low organic carbon content in 70.37% of the soil samples. Macronutrient analysis showed low to medium range for nitrogen, phosphorus and sulphur with average values of 244.15 Kg/ha, 14.78 kg/ha and 10.60 mg/kg respectively whereas medium to high range of potassium (481.7 kg/ha) and high range of exchangeable calcium (11.82 mEq/100g) and magnesium (9.89 mEq/100g) were found. Micro-nutrient analysis showed low to high range for manganese and zinc with values ranging from 3.08 to 56.1 mg/kg and 0.58 to 19.62 mg/kg respectively, with iron in the medium to high range (5.1 to 72 mg/kg) while available copper (2.2 to 4.08 mg/kg) was in the high range in the tested samples. The current study is expected to help the farmers of the study location in providing guidelines required for long-term soil fertility management and to improve soil quality and for developing suitable crop varieties that can grow without any yield reduction.

Keywords: Macronutrient; micronutrient; nutrient status; physico-chemical; soil fertility.

1. INTRODUCTION

Soil gives medium for plant growth and support for animals and human activity. Soil health refers to soil quality and is described as the continued potential of soil which works as a vital living ecosystem that sustains human, plants and animals. Mostly the soils are supplemented with the chemical fertilizers, organic manures and composts in which they meet their nutritional requirements of plants [1]. Soil is the natural body of minerals and organic constituents, which differentiated into horizons of variable depths below in morphology, which differs from parent material, chemical composition, biological properties and their physical makeup [2]. The plant needs essential nutrients for their completion of life cycle, so deficiency of an essential nutrients element makes it impossible for plant to complete their vegetative and reproductive stages of their life cycle. So it will be necessary to analyse the soils to know the deficient nutrients and to add it in the right quantity. Requirement of macronutrients in plants is needed in relatively higher amounts than micronutrients [3].

Nitrogen is an important part of chlorophyll, nucleic acids, enzymes, amino acids and proteins, which promote root growth and induces vegetative growth. In plants, phosphorus works as energy storage in plant, stimulates root development and seed formation. Potassium acts as enzyme activator, it helps in disease and drought resistance in plants, helps in stomata functioning, and is also helpful in the formation and translocation of sugars and carbohydrate. Calcium, magnesium and sulphur are secondary nutrients which play a very important role in the growth and development of plants, it promotes nodule formation in nitrogen binding leguminous plants roots [4]. “The capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain plant and animal productivity, maintain or improve water and air quality, and promote the plant and animal health” [5]. Uttar Pradesh is located in the fertile Indo-Gangetic plains region and, it is a significant contributor to the food security of the nation. Chiraigaon block is placed in Varanasi district in Uttar Pradesh.

A good knowledge of the physio-chemical and nutrient status of the soil is essential to find the quantity and type of fertilizers and manures or compost to be used in order to improve soil productivity, of a particular crop. It helps to avoid financial losses in unnecessary fertiliser application. In this context, the detailed soil survey of Chiraigaon block of 6 different villages, namely Umaraha, Khanpur, Bariyasanpur, Sion, Paterwan and Sathwa, were chosen for study to provide a site specific database for the planning optimum and the efficient use of soil nutrients status, in Chiraigaon block, Varanasi Uttar Pradesh.

2. MATERIALS AND METHODS

2.1 Description of Study Location

2.1.1 Experimental site

Chiraigaon block is one among the 8 blocks in Varanasi 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 [6]. From Chiraigaon block 54 representative surface soil samples were collected from cultivated field of six villages namely Umaraha, Khanpur, Bariyasanpur, Sivon, Paterwan and Sathwa.

2.1.2 Weather and climate

The climate of Chiraigaon block of Varanasi is mild and generally warm and temperate. The rainfall in Varanasi is significant, with precipitation even during the driest month. The Köppen-Geiger climate classification is humid subtropical climate Cfa [7]. In Varanasi, the average annual temperature is 25.7 °C and the annual rainfall around 982 mm with the lowest precipitation in April (average of 6 mm) [8].

2.1.3 Soil characteristics

The soils of Varanasi districts resembles that of the alluvial plains of river Ganga and varies from sandy, sandy loam, clay loam, 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-maize, wheat-mustard, barley, vegetables.

2.2 Methods of Sampling and Processing

2.2.1 Collection of soil samples

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

2.2.2 Processing of soil samples

Surface soil samples were collected and air-dried 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 particle density, bulk density, pH, electrical conductivity, water holding capacity and organic carbon were determined in the collected soil samples.

2.2.4 Determination of particle density and bulk density

The particle density and bulk density were determined by the help of Pycnometer described by Black (1965).

$$\text{Particle density} = \frac{Ws}{(W2+Ws)-W3}$$

Where,

'Ws = Mass of soil
W_2 = Mass of pycnometer + water
W_3 = Mass of pycnometer + water + soil

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

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-

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

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 samples were estimated by Walkey and Black method of wet oxidation, using the formula-

$$\%\ \text{Organic carbon} = Organic\ Carbon\ \frac{(B-C)}{Weight\ of\ the\ soil}\ \text{X } 0.0003 \text{ X } 100$$

Where,

A = Volume of 0.5N ferrous ammonium sulphate required to neutralise 10 ml of 1N of $K_2Cr_2O_{7\ i.e.}$ blank titration (blank reading)
B = Volume of 0.5N ferrous ammonium sulphate needed for titration of soil sample (reading with soil)

2.2.8 Determination of available nitrogen

The available nitrogen 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}) = $\frac{(S-V)\times 0.02\times 14\times 2.24\times 106}{1000\times 5}$

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 $NaHCO_3$ 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 exchangeable calcium

The estimation of exchangeable calcium in soil sample was determined by use of neutral normal ammonium acetate solution which was given by Jackson, 1973.

2.2.12 Determination of exchangeable calcium and magnesium

The estimation of exchangeable calcium + magnesium in soil was determined by use of neutral normal ammonium acetate solution, given by Jackson, 1973.

Amount of Ca + Mg (mEq L^{-1}) = $\frac{R\ X\ Normality\ of\ EDTA\ X\ 1000}{Aliquot\ (ml)\ taken}$

Amount of Ca + Mg (mEq 100g^{-1}) = $\frac{100}{Soil\ wt.(g)}\ X\ \frac{Extracted\ Volume\ (ml)}{100}\ X\ Ca\ in\ mEq\ L^{-1}$

Amount of Mg (mEqL^{-1}) = Ca + Mg (mEq L^{-1}) – Ca (mEq L^{-1})

Where, R= Volume (ml) of standard EDTA used in titration

2.2.13 Determination of available sulphur

Estimation of sulphur in the soil by Turbidity method (Chesnin and Yien, 1950).

Available sulphur (mg kg^{-1}) = $R\ X\ \frac{50}{10}\ X\ \frac{1}{10}$

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

2.2.14 Available micronutrient

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

2.2.15 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 Bulk Density

This study showed that the bulk density of soil samples ranged from 1.08 to 1.6 mg m^{-3} with a mean value of 1.22 mg m^{-3} (Table 1). The highest bulk density was observed at Sivo village whereas the lowest bulk density was observed at the Paterwan village. 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 Lego and Buraka [9].

3.2 Particle Density

The particle density values ranged from 2.08 to 2.67 Mg m^{-3} with a mean value of 2.37 Mg m^{-3} (Table 1). The standard deviation of particle density was 0.12 and the coefficient of variation was 5.19 %. The highest particle density was observed at Umraha village whereas the lowest occurred at Bariyasanpur village.

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

Soil Parameter	Mean	Range	S.D. (±)	C.V (%)
Bulk density (Mg m^{-3})	1.22	1.08 – 1.66	0.11	9.42
Particle density (Mg m^{-3})	2.37	2.08 – 2.67	0.12	5.19
Water holding capacity (%)	40.12	29.80 – 51.70	5.40	13.60
pH	7.52	7.10 – 8.30	0.30	4.00
Organic carbon (%)	0.59	0.24 – 0.95	0.19	33.35
EC(dSm^{-1})	1.45	0.18 – 2.85	0.47	33.05

3.3 Water Holding Capacity

Soil samples' collected from study locations showed water holding capacity from 29.80 to 51.70 %, with an average value of 40.12 % (Table 1). The standard deviation of water holding capacity was 5.4 and the coefficient of variation was 13.6%. The result showed that variation in water holding capacity was probably due to organic carbon content in the soil. Similar results were also reported by Tale and Ingole [10].

3.4 Soil pH

The values of pH ranged from 7.1 to 8.3, with a mean value of 7.52 with an SD value of 0.30 and a CV value of 4.0 % (Table 1). The pH of the cultivated lands of the Chiraigaon block of Varanasi district was mostly (59.25 %) slightly alkaline in reaction while 11.11% of the area moderately alkaline and the rest 29.64 % area was neutral.

3.5 Soil EC

The EC of soil samples ranged from 0.18 to 1.68 dSm^{-1} with an average value of 0.57 dSm^{-1} with standard deviation and coefficient of variation of 0.24 and 43.70 %, respectively (Table 1). The results showed that 87.04 % of the samples were in the acceptable range, and 12.96 % of the samples were slightly higher than the permissible range [11].

3.6 Soil Organic Carbon

The organic carbon content of soil samples ranged from 0.21 to 0.76 %, with a mean value of 0.45 % (Table 1). The standard deviation of organic carbon content was 0.11, and the coefficient of variation was 25.06. The lowest organic carbon value was observed at the Sion village whereas the highest value observed at Paterwan village of Chiraigaon block. The majority of the soil samples was found to be low in organic carbon (70.37 %) 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.

3.7 Status of Available Primary Macronutrients in the Soil

3.7.1 Available nitrogen

Nitrogen content in soil samples ranged from 163.07 to 305.21 kg ha^{-1} with a mean value of 244.15 kg ha^{-1} (Table 2). The standard deviation and coefficient of variation of the available nitrogen were 42.02 and 17.21 %, respectively. The lowest nitrogen content was observed in Bariyasanpur while the highest nitrogen content was in Sion village. The nitrogen content of the study region is low probably due to low organic carbon content present in the soil (Singh and Bijay) [12].

3.7.2 Available phosphorus

Available phosphorus content of soil samples ranged from 8.8 to 22.09 kg ha^{-1} with an average value of 14.78 kg ha^{-1} (Table 2). The lowest value of phosphorus content was observed at Umraha village, whereas the highest value was at Paterwan village. 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 protect the P fixation [13].

3.7.3 Available potassium

Available potassium content of soil ranged from 111.98 to 305.43 kg ha^{-1} with a mean value of 229.11 kg ha^{-1} (Table 2). The lowest phosphorus value was observed at Paterwan, while the highest was at Sathwa village, with SD and CV value of 51.05 and 22.28%, respectively. In the study region potassium content is high, may be due to elite, rich potassium minerals found in the soil [14].

Table 2. Statistical data on primary macronutrients of soil

Soil parameters	Mean	Range	SD ±	C.V. (%)
Nitrogen (kg ha^{-1})	244.15	163.07-305.21	42.02	17.21
Phosphorus (kg $ha^{-1)}$	14.78	8.8 – 22.09	3.80	25.71
Potassium (kg ha^{-1})	229.11	111.98-305.43	51.05	22.28

3.8 Status of Available Secondary Macronutrients in the Soil

3.8.1 Available calcium

Calcium content of soil samples ranged from 6.2 to 19.3 mEq $100g^{-1}$ with a mean value of 11.82 mEq $100g^{-1}$ (Table 3). The lowest calcium content was observed in Patrewan village, while; the highest calcium content was observed in Umraha village. High calcium content was observed for all locations in this study.

3.8.2 Available magnesium

The magnesium content of soil the samples ranged from 2.9 to 18.1 mEq $100g^{-1}$ with a mean value of 9.89 mEq $100g^{-1}$ (Table 3). The lowest calcium content was observed in Khanpur village, whereas the highest value was observed at Sathwa village.

3.8.3 Available sulphur

As can be seen in Table 3, the sulphur content of the soil samples ranged from 3.45 to 15.8 mg kg^{-1} with an average value of 10.60 mg kg^{-1}. The lowest sulphur content was observed at Khanpur village, while the highest was at Bariyasanpur village.

3.9 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 micronutrients (Fe, Cu, Zn, Mn) concentration in the soil. The analysed data of the micronutrients of soil are given in Table 4.

3.9.1 Available iron

The soil samples' iron content ranged from 5.1 to 72 mg kg^{-1} with a mean value of 29.41 mg kg^{-1}. The lowest Fe content was observed at Umraha village while the highest Fe content was at Khanpur village. Of the soil sampled, 9.25 %, were in medium range iron concentration, 90.75 % were in high, and 0 % were in low iron concentration similar results were reported by Kumar and Babel [15].

3.9.2 Available copper

The values of copper in the studied samples ranged from 2.2 to 4.08 mg kg^{-1} with a mean value of 3.14 mg kg^{-1} (Table 4). The values of standard deviation and coefficient of variation of Cu were 0.51 and 16.27 %, respectively. Out of total 54 soil samples, 100 % of samples were high in available copper content as per the critical limit suggested by Lindsay and Norvell [16].

3.9.3 Available zinc

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 4). The values of standard deviation and coefficient of variation of zinc were 5.32 and 67.4 %, respectively. Out of 54 soil samples, 88.88% of the samples were high in zinc, 9.28% had medium in Zn content and 1.84% sample low in zinc content.

3.9.4 Available manganese

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. 96.29 % of soil samples are high in available Mn content, and 3.70 % of the samples are at the low level of Mn content (as per the critical limit suggested by Lindsay and Norvell, 1978 [16].

3.10 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 Chiraigaon block Varanasi district were medium for organic carbon and low in nitrogen and phosphorus and medium for potassium and high in micronutrient cations (Fe, Cu, Zn, Mn) (Table 5).

Table 3. Statistical data on secondary macronutrients of soil

Soil parameters	Range	Mean	SD±	C.V. (%)
Magnesium (mEq $100g^{-1}$)	2.9 - 18.1	9.89	3.04	30.80
Calcium (mEq $100g^{-1}$)	6.2 – 19.3	11.82	3.13	26.49
Sulphur (mg kg^{-1})	3.4 – 15.8	10.60	2.44	23.06

Table 4. Statistical data on available micronutrients of soil

Soil parameters	Range	Mean	SD±	C.V. (%)
Available Fe (mg kg^{-1})	5.18- 72.0	29.41	13.42	45.65
Available Cu (mg kg^{-1})	2.20-4.08	3.14	0.51	16.27
Available Zn (mg kg^{-1})	0.58-19.62	7.89	5.32	67.46
Available Mn (mg kg^{-1})	3.08-56.18	26.37	9.68	36.74

Table 5. Nutrient Index (NI) values of chiraigaon block of Uttar Pradesh

No.	Available nutrient	Available nutrient	Category
1	Nitrogen	1.29	Low
2	Phosphorus	1.64	Low
3	Potassium	1.96	Medium
4	Sulphur	1.57	Low
5	Calcium	1.31	Low
6	Magnesium	3.00	High
7	Iron	2.90	High
8	Copper	3.00	High
9	Zinc	2.80	High
10	Manganese	2.92	High

4. CONCLUSION

Based on the experimental results, it is concluded that, in the soils of Chiraigaon block of Varanasi district, bulk density was observed low for high organic carbon content soil and variation in water holding capacity was observed variation with organic carbon content in the soil. The results showed 70.37 % of the soil samples were low, 27.7 % of the soil samples were medium and 1.8 % of the soil samples were high in organic carbon content. According to the Nutrient Index value, nitrogen, phosphorus, calcium and sulphur content were low, potassium content in the medium category and magnesium, iron, copper, zinc and manganese content in high category. Nitrogen is actually considered the most important component, for supporting plant growth, hence it is recommended to use composted manure and green manure for supply of nitrogen with chemical fertilizer application for high yielding crops. For low phosphorus content it is recommended to supply organic amendments which are rich sources of phosphorus like raw bone meal, poultry manure which should increases the phosphorus availability of the soil. For low sulphur content in the soil, it is recommended to add poultry manure or gypsum fertiliser. Potassium content in soil helps in disease and drought resistance in the soil, so adequate amount of potassium, such as found in pig manure is recommended for adding to the soil. The micronutrients (Fe, Cu, Zn, Mn) of the soil content was in the high category. The information of the present study could be useful for farmers regarding the quality of produce, increasing the percentage yield of crops through soil conservation and better environmental protection.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ahmad Rizwan, Muhammad Arshad, Azeem Khalid, Zahir A. Zahir. "Effectiveness of organic-/bio-fertilizer supplemented with chemical fertilizers for improving soil water retention, aggregate stability, growth and nutrient uptake of maize (*Zea mays* L.)." Journal of Sustainable Agriculture. 2008;31(4):57-77.

2. Osman, Khan Towhid. Soils: principles, properties and management. Springer Science & Business Media; 2012.
3. Roosta Hamid R, Mohsen Hamidpour. "Effects of foliar application of some macro-and micro-nutrients on tomato plants in aquaponic and hydroponic systems." Scientia Horticulturae. 2011;129 (3):396-402.
4. Vatansever Recep, Ibrahim Ilker Ozyigit, Ertugrul Filiz. "Essential and beneficial trace elements in plants, and their transport in roots: A review." Applied Biochemistry and Biotechnology. 2017; 181:464-482.
5. Doran John W, Michael R. Zeiss. "Soil health and sustainability: Managing the biotic component of soil quality." Applied Soil Ecology. 2000;15(1):3-11.
6. Yadav Amrendra Kumar, Tanisha Gehlot AN, Prince SR, Mishra A. K. Singh, Rajan Chaudhary. "Rainfall variability analysis of eastern plain zone of Uttar Pradesh."
7. Chen Fangyuan, Siya Chen, Mengmeng Jia, Mingyue Jiang, Zhiwei Leng, Libing Ma, Yanxia Sun, Ting Zhang, Luzhao Feng, Weizhong Yang. "Exploring meteorological impacts based on köppen-geiger climate classification after reviewing China's response to COVID-19." Applied Mathematical Modelling. 2023;114:133-146.
8. Nistor Mărgărit-Mircea, Praveen K. Rai, Vikas Dugesar, Varun N. Mishra, Prafull Singh, Aman Arora, Virendra Kumar Kumra, Iulius-Andrei Carebia. "Climate change effect on water resources in Varanasi district, India." Meteorological Applications. 2020;27(1):e1863.
9. Agegn Asmachew. "Effect of blended npsznb fertilizer rates on yield and quality of soybeaN [*Glycine max* (L.) Merrill] varieties in Guangua district, North-West Ethiopia." PhD diss; 2021.
10. Tale Ku Smita, Sangita Ingole. "A review on role of physico-chemical properties in soil quality." Chemical Science Review and Letters. 2015;4(13):57-66.
11. Farid Hafiz Umar, Zahid Mahmood-Khan, Ijaz Ahmad, Aamir Shakoor, Muhammad Naveed Anjum, Muhammad Mazhar Iqbal, Muhammad Mubeen, Muhammad Asghar. "Estimation of infiltration models parameters and their comparison to simulate the onsite soil infiltration characteristics." International Journal of Agricultural and Biological Engineering. 2019;12(3):84-91.
12. Singh Bijay. "Are nitrogen fertilizers deleterious to soil health?" Agronomy. 2018;8(4):48.
13. Singh RP, Mishra SK. "Available macro nutrients (N, P, K and S) in the soils of Chiraigaon block of district Varanasi (UP) in relation to soil characteristics." Indian Journal of Scientific Research. 2012;3(1): 97-100.
14. Covacevich Fernanda, Hernán E. Echeverría, Luis AN Aguirrezabal. "Soil available phosphorus status determines indigenous mycorrhizal colonization of field and glasshouse-grown spring wheat from Argentina." Applied Soil Ecology. 2007; 35(1):1-9.
15. Kumar M, Babel AL. "Available micronutrient status and their relationship with soil properties of Jhunjhunu Tehsil, District Jhunjhunu, Rajasthan, India." Journal of Agricultural Science. 2011;3(2) :97.
16. Lindsay Willard L, WAa Norvell. "Development of a DTPA soil test for zinc, iron, manganese, and copper." Soil Science Society of America Journal. 1978; 42(3):421-428.

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