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Assessment of Soil Fertility Attributes in Selected Districts of Bundelkhand Region of Central India

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Authors' contributions

This work was carried out in collaboration among all authors. Authors MP and SKM conceptualized and wrote the first draft of the manuscript. Authors SK and SKM conducted the literature searches. Authors SKM, PG and MP conducted the laboratory works. All authors read and approved the final manuscript.

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ABSTRACT

An observational study was carried out to assess the soil fertility attributes of three districts (i.e. Jhansi, Datia and Tikamgarh) of the Bundelkhand region of central India. Soil samples were collected randomly from 0-15 cm soil depth using a soil auger with a diameter of 5 cm and followed the standard protocols for assessing the soil fertility attributes. A total number of samples were 58 (randomly selected sites). The soil reaction was neutral to strongly alkaline (pH 7.28-9.71) in nature. The electrical conductivity (EC) values were low (0.01- 0.89 dS m^{-1}) indicating that of no harmful effect on crop growth. Most of the soils were found under low category of soil organic carbon (SOC), available nitrogen (N) and phosphorus (P). The available potassium (K) and sulphur (S) were found in the range between 68.32 to 781.76 kg ha^{-1} and 7.97 to 273.24 kg ha^{-1}, respectively. With respect to DTPA extractable micronutrients i.e. copper (Cu) and zinc (Zn) were in sufficient range but boron (B), iron (Fe), and manganese (Mn) were in low category. Based on the Soil Nutrient Index (SNI), the soils of the study area were found in low fertility status for N and P and medium in SOC and K. The SNI for S was ranging from medium to high fertility category. Thus, SOC, N, P, K, B, Fe and Mn

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were the key soil fertility constraints in the Jhansi, Datia and Tikamgarh districts of the Bundelkhand region. The balanced use of chemical fertilizers and micronutrients (B, Fe and Mn) based on the soil test results along with the combination of bio-fertilizers and organic manures as an integrated nutrient management (INM) approach could greatly help in maintaining the soil fertility and sustainable crop production in Bundelkhand region of central India.

Keywords: Organic carbon; available nutrients; micronutrients; soil nutrient index; Bundelkhand region.

1. INTRODUCTION

Soil is one of the most important natural resource, not only essential for the food, fodder and fibre production but also to maintain the local, regional and global environmental sustainability [1]. As suggested by [2], it is necessary to manage natural resources in a sustainable way for changing human needs while maintaining and improving the environmental quality. Farmers in Asia especially in India are following the conventional and cultural production practices in agriculture to meet the feed, fibre and fodder requirements since from the beginning of agriculture. In India, sustainability of crop production systems has also become a main concern in order to meet the food demand of ever increasing population. About 57% of total geographical area of India is suffering from different types of land degradation problems [3]. Further, India needs 350 million tons (mt) of food grains to meet the demand of the projected population of 1.48 billion by 2030 [4].

Soil fertility defined as the inherent capacity of a soil to supply essential nutrients to plant in adequate amount, in correct proportion and at the right time for their optimum growth. Variation in nutrient supply is a natural phenomenon and some where it may be sufficient while some where deficient. Within a soil, variability may exist depending upon the pedogenic and artificial factors. In India especially in the central parts of the country the climate is semi-arid with high evapotranspiration, high temperature and sparse vegetation. Those factors have a huge influence on the loss of nutrients in the form of volatilization, and leaching (due to light soils). The agricultural activities further in these regions are under pressure of climate change and various socio-economic conditions. All these factors coupled with other factors make these soils less fertile and poor to use for agriculture. In order to increase the agricultural productivity and make these soils more fertile and highly useful for agriculture then it is time to address the water shortage and soil infertility problems in these regions [5,6].

The country's present and future food demand can only meet by exploiting the huge untapped potential of semi-arid/*rainfed* agriculture through improved management of land, water, nutrients and other natural resources [7,8,9]. We have to produce more food from less land in future through sustainable utilization of natural resources. Bundelkhand region located in the central part of the country is well known for unexplored, low fertile and poorly developed soils due to excessive drainage (due to light soils), low soil depth, very low water retention capacity and low content of organic matter and crust formation on the soil surface [10]. This region also have faced repeated drought from 2004 to 2007 due to scarcity and unevenness of rainfall which lead to discrepancy of crop planning, policy making, and development of intervention schemes [11]. Thus, the characterizing of soils and assessing nutrient supply capacity of soils in this region is essential to ensure and enhance the agriculture sustainability. Therefore, an observational study was undertaken to characterization of the soils on the basis of soil fertility attributes of some selected districts i.e. Jhansi, Datia and Tiakamgarh of Bundelkhand region of central India.

2. MATERIALS AND METHODS

2.1 Study Area

Bundelkhand region covered about 7.16 million ha area in central India. The annual rainfall of the region is around 908 mm, which is mostly received during June to August (southwest monsoon). The average maximum and minimum temperature of the region is 32.7ºC and 25.1ºC, respectively. The soil is low in organic carbon (OC), available nutrients (plant available N and P), and water holding capacity. The productivity of these soils is low to medium in range. The soil

samples were collected from different locations of three districts *viz.* Jhansi, Datia and Tikamgarh. The sampling sites were selected randomly based on the variability of the fields (Fig. 1).

2.2 Soil Sampling and Analysis

The soil samples were collected from plough depth (0-15 cm) in selected locations with the help of soil auger (diameter 5 cm) and stored in cloth bags until further analysis [12]. A total of 58 samples were collected in October, 2020. Samples were collected from ten spots of one site and pooled as one by following the quartering technique and considered as one sample. Soil samples were air dried, processed and analysed using standard procedures described by varies researchers i.e. for pH and EC (electrical conductivity) [13], soil organic carbon (SOC) [14], available macro nutrients; Nitrogen (N, alkaline permanganate method), phosphorous (P, Olsen's method), potassium (K, Flame photometer method), sulphur (S), DTPA extractable micro nutrients; zinc (Zn), iron (Fe), manganese (Mn), copper (Cu) and boron (B) using standard procedures given by [15].

2.3 Statistical Analysis

Descriptive analysis (mean, range, standard error, standard deviation and coefficient of variation) of soil attributes were computed using the R software. Soil fertility rating (low, medium, and high) were determined based on the [16] criteria.

Similarly, the soil nutrient index (SNI) was calculated using the following [1]:

$$SNI = (N_L \times 1 + N_M \times 2 + N_H \times 3) / N_T)$$

Where,

N_L = Number of samples under low nutrients status
N_M = Number of samples under medium nutrients status
N_H = Number of samples under high nutrients status
N_T = Total number of samples analysed in the given area

Soil nutrient index was interpreted according to the values suggested by (Table 1) [17].

3. RESULTS AND DISCUSSION

3.1 Soil pH and EC

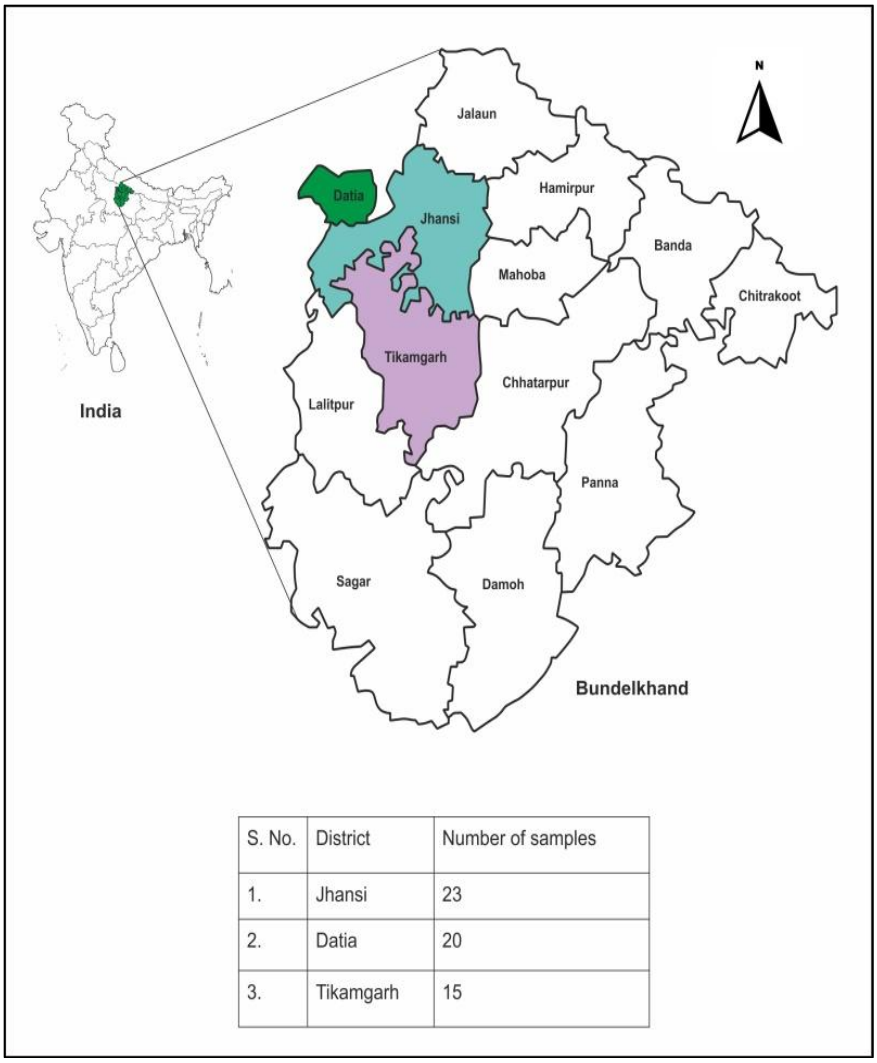
Soil pH is the most important attribute of the soil because it directly impact the nutrient availability and crop growth. The data showed that soils of all three districts were neutral to strongly alkaline (7.28 to 9.71) in nature (Table 2) with a mean value of 8.06 in Jhansi, 8.21 in Datia and 7.82 in Tikamgardh. The neutral to strongly alkaline pH of these soils can be attributed to the presence of high degrees of base saturation and useful for mostly grown of field and horticulture crops. Gabhane et al. [18] also reported a neutral to moderately alkaline pH (7.5-8.03) soils in Vidarbha region of Maharashtra. Pandey et al. [19] reported that available S had significant positive correration with pH in Inceptisols of central (UP) India. The EC values of these districts varied from 0.01 to 0.89 dS m^{-1} (Table 2). The EC of all the soil samples were in acceptable limit (<1.0 dS m^{-1}) for crop growth indicating higher fertility. In general, the arid and semi-arid regions soils are dominated by the carbonates of calcium, whereas the EC of the soil is governed by carbonates and sulphates of Na, which is the reason for the low EC in this region. The optimal pH and EC of soil helps in nutrient availability, reduction of toxic elements effects, and increase in soil microbial activities [20].

3.2 Soil Organic Carbon (SOC)

SOC is considered as a key indicator for soil fertility and sustainability of agricultural systems. It has been major source of plant nutrients (N, P, S and micronutrients) besides promoting many soil physical properties. The SOC ranges from 0.16 to 1.07% with a mean value of 0.57, 0.74 and 0.70% in Jhansi, Datia and Tikamgarh, respectively (Table 2). About 48% in Jhansi, 25% in Datia, and 34% in Tikamgardh soils were low in SOC. Lower SOC in the Bundelkhand region may be due to the prevailing high temperature as well as good soil aeration accelerate the oxidation rate of organic matter [21]. This finding corroborates that of [22] who observed low organic matter content (0.22- 0.74%) in the soils of Karauli district of Rajasthan (India)

3.3 Primary and Secondary Nutrients

The soil samples of Jhansi, Datia, and Tikamgarh district are low to medium (105.05-278.16 kg ha^{-1}, 183.45-232.37 kg ha^{-1}, and 135.78-325.83 kg ha^{-1}, respectively) in available



S. No.	District	Number of samples
1.	Jhansi	23
2.	Datia	20
3.	Tikamgarh	15

Fig. 1. Location map of selected sites with number of samples collected from each location

nitrogen with a mean value of 177.89, 209.02 and 207.10 kg ha^{-1}, respectively. It low to medium range of N may be linked with low organic matter content, losses of nitrogen due to leaching (light soils), high denitrification rate in semi-arid climate, and lack of bio-fertilizer, green manures and nitrogenous fertilizers use. Almost 100% soil samples rated low for nitrogen in Jhansi and Tikamgardh whereas, 40% soil samples were low in Datia. Similar results were reported by [23] that the 90% of total soil samples of Rajnagar block, Birbhum District of west Bengal were found under the category of low nitrogen content.

Status of phosphorus falls between 2.40 to 30.40 kg ha^{-1} with a mean value of 8.51, 9.53 and 9.55 kg ha^{-1} in Jhansi, Datia, and Tikamgarh districts, respectively. This is may be due to high soil pH as well as high $CaCO_3$ content in the soils. Apart from this a number of factors are responsible for available phosphorous content of the soils such as chemical fertilization in past, application of biofertilizers, organic matter content, soil management, and agricultural practices [24]. Similar finding were also reported by [25] wherein they found available P was low (1.25-18.42 kg ha^{-1}) in the soils of Ahmednagar district of Maharashtra, India.

Table 1. Soil nutrient index rating chart

Soil nutrient index	Value
Low	<1.67
Medium	1.67-2.33
High	>2.33

Table 2. Soil fertility status of Jhansi, Datia and Tikamgardh districts of Bundelkhand region

District	Descriptive statistics	pH	EC (dS m^{-1})	SOC (%)	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K(kg ha^{-1})	Available S (kg ha^{-1})
Jhansi	Mean	8.06	0.18	0.57	177.89	8.51	189.28	150.46
	Standard error	0.12	0.04	0.05	8.51	1.26	16.58	33.61
	Standard deviation	0.59	0.08	0.15	20.82	1.06	27.50	29.17
	Minimum	7.50	0.03	0.16	105.05	2.40	68.32	7.97
	Maximum	9.71	0.89	1.07	278.16	30.40	517.44	273.24
	CV (%)	7.38	20.60	43.53	22.95	51.28	67.36	39.02
Datia	Mean	8.21	0.12	0.74	209.02	9.53	306.70	128.82
	Standard error	0.12	0.01	0.05	9.40	1.45	16.94	17.79
	Standard deviation	0.22	0.03	0.18	37.00	1.09	30.54	18.96
	Minimum	7.28	0.03	0.33	135.78	2.96	94.08	40.85
	Maximum	9.94	0.39	1.68	325.83	27.58	781.76	233.45
	CV (%)	7.60	33.97	37.71	22.49	57.18	40.23	49.06
Tikamgardh	Mean	7.82	0.04	0.70	207.10	9.55	154.56	64.97
	Standard error	0.13	0.01	0.05	10.35	1.25	18.92	10.48
	Standard deviation	0.31	0.01	0.12	20.25	3.03	22.32	13.44
	Minimum	7.41	0.02	0.50	183.45	5.68	88.48	39.85
	Maximum	8.14	0.07	0.84	232.37	18.25	203.84	93.66
	CV (%)	3.95	28.63	17.84	11.23	22.69	27.38	36.07

Table 3. Micro nutrients status in soils Jhansi, Datia and Tikamgardh districts of Bundelkhand region

District	Descriptive statistics	Zn (mg kg^{-1} soil)	B (mg kg^{-1} soil)	Fe (mg kg^{-1} soil)	Mn (mg kg^{-1} soil)	Cu (mg kg^{-1} soil)
Jhansi	Mean	2.77	0.95	18.13	81.23	350.49
	Standard error	1.12	0.13	2.51	13.27	16.81
	Standard deviation	1.40	0.35	12.06	18.43	24.28
	Minimum	0.73	0.02	5.78	0.02	11.88
	Maximum	26.71	2.74	44.52	666.40	1061.40
	CV (%)	90.86	50.80	66.48	88.07	72.47
Datia	Mean	1.68	1.73	17.91	167.56	17.27
	Standard error	0.17	0.48	2.69	12.61	1.67
	Standard deviation	0.88	0.43	3.48	13.05	8.38
	Minimum	0.68	0.04	5.78	0.02	11.88
	Maximum	3.62	11.25	61.32	610.40	431.84
	CV (%)	52.72	40.24	75.27	27.15	48.51
Tikamgardh	Mean	1.76	0.43	12.73	479.36	13.62
	Standard error	0.14	0.25	2.19	51.50	1.74
	Standard deviation	0.33	0.37	4.91	72.93	3.89
	Minimum	1.50	0.02	5.78	0.02	11.88
	Maximum	2.32	1.27	17.36	1114.40	20.58
	CV (%)	18.66	32.44	38.59	98.66	28.57

Table 4. Soil Nutrient index and percentage distribution of studied soil properties Jhansi, Datia and Tikamgardh districts of Bundelkhand

Parameters	Jhansi					Datia					Tikamgardh				
	L	M	H	NI	R	L	M	H	NI	R	L	M	H	NI	R
SOC (%)	48	22	30	1.83	M	25	30	45	2.20	M	34	53	13	1.80	M
N (kg ha^{-1})	100	-	-	1.00	L	40	60	-	1.60	L	100	-	-	1.67	L
P (kg ha^{-1})	87	9	4	1.17	L	80	15	5	1.25	L	67	26	7	1.40	L
K (kg ha^{-1})	43	44	13	1.70	M	15	50	35	2.20	M	7	60	33	2.27	M
S (kg ha^{-1})	17	9	74	2.57	H	10	85	5	1.95	M	-	33	67	2.67	H
Zn (mg kg^{-1})	-	39	41	2.61	H	-	70	30	2.30	M	-	33	67	2.67	H
B (mg kg^{-1})	26	74	-	1.74	M	15	70	15	2.00	M	40	60	-	1.60	L
Fe (mg kg^{-1})	-	22	78	2.78	H	35	65	-	1.65	L	13	67	20	2.07	M
Mn (mg kg^{-1})	70	-	30	1.61	L	50	-	50	2.00	M	27	40	33	2.07	M
Cu (mg kg^{-1})	0	9	91	2.91	H	5	5	90	2.85	H	-	67	33	2.33	M

**L=Low; M=Medium; H=High; NI=Nutrient Index; R=Remarks*

A wide range of soil potassium content was also observed in the soils of Jhansi, Datia, and Tikamgardh. Results show that the available K ranges from 68.32 to 781.76 kg ha^{-1} with a mean value 189.28, 306.70 and 154.56 kg ha^{-1} in the soils of Jhansi, Datia, and Tikamgarh districts, respectively. This type of trend possibally due to difference in K release rate from the clay and differences in the rate of K fertilization.

Sulphur content in the soils ranges from 7.97 to 273.24 kg ha^{-1} with a mean value of 150.46, 128.82 and 64.97 kg ha^{-1} in Jhansi, Datia and Tikamgarh districts, respectively. Both maximum and minimum available S was found in Jhansi district compared to Datia and Tikamgarh. Most of soil samples were in the range of medium to high category in available sulphur; this may be attributed due to continuous use of single super phosphate (SSP, Sulphur containing fertilizer) as a source of P and/or sulphur containing minerals in the soil.

3.4 Micronutrients

Micronutrients are widely distributed in all the analysed soil samples. Among the DTPA extractable micronutrients i.e. Zn was ranged from 0.68 to 26.71 mg $kg^{-1}$of soil; Fe ranged from 5.78 to 61.32 mg kg^{-1}; Mn ranged from 0.02 to 1114.40 mg kg^{-1}, Cu ranged from 11.88 to 1061.40 mg kg^{-1}, and B ranged from 0.02 to 11.25 mg kg^{-1} (Table 3). The available Cu (copper) and zinc (Zn) were in sufficient range but the boron (B), iron (Fe), and manganese (Mn) were low in category in Tikamgardh, Datia, and Jhansi, respectively. The availability of micronutrient in a soil is governed by several factors such as soil pH, EC, organic matter content, micronutrient status of soils, clay content of the soil, soil microbial activities, use of trace element containing fertilizers, status of macro, and other micronutrients content of the soil. Similar findings were also reported by [26] at Agricultural Farm of Rajiv Gandhi South Campus (Banaras Hindu University), Barkachha, Mirzapur, Uttar Pradesh, India.

3.5 Soil Nutrient Index

Soil nutrient index (SNI) was calculated for all the soil attributes except soil pH and EC. On the basis of rating suggested by [17]. SNI values were interpreted in three categories i.e. low, medium and high. Based on the SNI values, the soil fertility status of the samples collected was uneven. The SNI value for SOC was under low to medium in category while the available nitrogen and phosphorus were under low category in all the studied soil samples (Table 4). The SNI value for available potassium was medium. Sulphur content was high in soils of Jhansi and Tikamgarh (SNI: 2.57 and 2.67, respectively) whereas in Datia was in medium category with SNI value of 1.95. In case of micro nutrient status, the soils of Jhansi are high in Zn, Fe and Cu (SNI: 2.61, 2.78 and 2.91, respectively), whereas medium in B (SNI: 1.74) and low in Mn (SNI: 1.61). The soils of Datia district are high in Cu (SNI: 2.85), medium in Zn, B, and Mn (SNI: 2.30, 2.00 and 2.00, respectively), and low in Fe (SNI: 1.65). The soils of Tikamgarh are high in Zn (NI: 2.67), medium in Fe, Mn, and Cu (SNI: 2.07, 2.07 and 2.33, respectively), whereas low in B (SNI: 1.60). According to [27] the SNI for NPK was low-low-high. As per [28] NPK status of Uttar Pradesh was low, medium, and medium, respectively and the micronutrients were in sufficient amount.

4. CONCLUSION

The present study suggest that the soils of Jhansi, Datia and Tikamgarh are mostly neutral to strongly alkaline in nature. The SOC ranged from low to medium category in all the districts. Soil fertility attributes indicated that soils are low in available nitrogen, phosphorus and medium in available potassium. Availability of micronutrients *viz.* Cu and Zn were in sufficient in range and B, Fe, and Mn were in low category in Tikamgardh, Datia and Jhansi, respectively. It is clearly indicating the need of effective and proper nutrient management for better crop production and the sustainability of soil nutrient supply in this region. Therefore, farmers are advised to use chemical fertilizers and micronutrients (B, Fe and Mn) based on the soil test results along with bio-fertilizers, and organic manures as an integrated nutrient management (INM) approach can be a viable option in this region for maintaining soil fertility and sustainable crop production. However, in depth studies are required to explore the overall fertility status of entire Bundelkhand region for better planning of cropping systems and effective nutrient management practices.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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