Available Micronutrient Status and Their Relationship with Soil Properties of Jhunjhunu Tehsil, District Jhunjhunu, Rajasthan, India

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Abstract

The aim of this study was to evaluate available micronutrient (Fe, Cu, Zn, Mn and B) status and their relationship with soil properties. To study this, there were seventy surface soil (0-30 cm depth) and plant samples, each collected from wheat growing fields of Jhunjhunu tehsil. The soils were analyzed for physico-chemical properties and status of available micronutrients. Grain and straw samples of wheat plant separately analyzed for micronutrient contents. The sand, silt and clay content of the soil ranges from 76.70 to 90.40, 1.30 to 7.50 and 5.20 to 12.90 per cent, respectively and these soils categorized as sandy, loamy sand and sandy loam. The soils were moderately calcareous in nature and having $CaCO_3$ content ranges from 3.90 to 12.00 per cent. The analyzed samples showing lower in organic carbon and CEC and their ranges from 0.06 to 0.43 per cent and 2.40 to 10.40 cmol (p^+) kg^{-1}, respectively. The pH (8.10 to 9.20) and EC (0.20 to 2.14 dSm^{-1}) values indicated that soils were found to be moderately alkaline and non-saline in nature. The 90 per cent of analyzed soil samples were found to be deficient in iron and 70 per cent deficient in zinc and their values ranges from 1.22 to 5.87 and 0.12 to 1.30 mg kg^{-1}, respectively. While the remaining micronutrients (Cu, Mn and B) shown to be sufficient and their values ranges between 0.17 to 3.32, 2.03 to 5.67 and 0.37 to 1.51 mg kg^{-1}, respectively. The availability of micronutrients indicating positive and significantly correlated with silt, clay, organic carbon and CEC of soils, whereas, negative and significantly correlated with sand, calcium carbonate and pH of the soils. The availability of micronutrients in wheat grains and straw positively correlated with silt, clay, organic carbon and CEC and negatively correlated with sand, $CaCO_3$ and pH of soils.

Keywords: Physico-chemical characteristics, Micronutrients

1. Introduction

Soil plays a major role in determining the sustainable productivity of an agro-ecosystem. The sustainable productivity of a soil mainly depends upon its ability to supply essential nutrients to the growing plants. The deficiency of micronutrients has become major constraint to productivity, stability and sustainability of soils (Bell and Dell, 2008). Micronutrient contents of soil and their availability to plant are assessed by the mineral present and weathering processes. Uptake of micronutrient is affected by the presence of major nutrients due to either negative or positive interactions (Fageria, 2001). High phosphate content of soils or high fertilization with phosphate may reduce the uptake of zinc and other nutrients (Dadhich and Somani, 2007 and Kizilgoz and Sakin, 2010). Thus, indiscriminate use of macronutrients may affect uptake of micronutrients.

Plants take their nutrients mostly from soil. It is well known that the optimum plant growth and crop yield depends not only on the total amount of nutrients present in the soil at a particular time but also on their availability which in turn is controlled by physico-chemical properties like: soil texture, organic carbon and calcium carbonate, cation exchange capacity, pH and electrical conductivity of soil (Bell and Dell, 2008). The soils of Agro-climatic zone IIA of Rajasthan (Transitional Plain of Inland Drainage), having the problem of sand dunes are characterized by light texture, low organic carbon content, high pH, low CEC and salinity/alkalinity problems (Shyampura *et al.,* 2002). These soil conditions are not favourable for adequate availability of micronutrients (Yadav and Meena, 2009). The Jhunjhunu tehsil comes under this zone (IIA) so that keeping these facts in view, the present investigation was undertaken to assess the status of available micronutrient (Fe, Cu, Mn, Zn and B), relationship with soil properties, their deficiency, sufficiency and relationship with their content in plant.

2. Materials and Methods

2.1 Study Area

Jhunjhunu tehsil is located in north-west part of the Jhunjhunu district (Rajasthan), India and situated between 28°13' north latitude and 75°04' east longitude and elevation 323 m (1059 feet) from mean sea level. The climate of the area is typically semi-arid. Rainfall and temperature are the two main elements of the climate. The rainfall is seasonal, erratic and not properly distributed and it varies between 300 to 500 mm annually which is mostly received during the month of July to September. In summer maximum temperature ranges between 35^0C to 48^0C and in winter the minimum temperature varies from 1^0C to 10^0C and sometimes it falls below 0^0C. Weather hazards are also not uncommon in this region; like storms during summer, fog during winter, nights are frosty which provide a great variation in temperature (Ghosh, 1991 and Shyampura *et al.*, 2002).

2.2 Soil, plant sampling and analysis

This study was designed to determine the status of micronutrients in wheat growing areas of Jhunjhunu tehsil. To carry out this experiment seventy sites were selected for the study (fig. 1). Represented soil samples were collected with wooden tools to avoid any contamination of the soils. Four to six pits were dug for each sample. From each pit sample was collected at a depth 0-30 cm. A composite sample of about 1 kg was taken through mixing of represented soil sample. All composite samples were dried, ground with wooden mottle and passed through 2 mm sieve. After sieving all the samples were packed in the polythene bags for laboratory investigations. Samples of wheat plants at harvesting stage were also collected from each sampling site from where soil samples were collected. Both straw and grain of plant samples were well processed separately in laboratory and analyzed for micronutrient (Fe, Cu, Zn, Mn and B). Standard analytical methods used in the analysis of soil and plant samples (Table 2).

2.3 Statistical analysis

The relationship between different soil characteristics and micronutrient contents in soils and plants were determined using correlation coefficients:

$$r = \sqrt{\frac{SP\ (xy)}{SS\ (x),\ SS\ (y)}}$$

Where: r = Correlation coefficient

SP (xy) = Sum product of x, y variables

SS (x) = Sum of square of x variable

SS (y) = Sum of square of y variable

3. Results

3.1 Soil properties

The range and mean values of analyzed soil properties (texture, calcium carbonate, organic carbon, pH, EC and CEC) given in Table 3. The textural classes of the soils under investigation were sandy, loamy sand and sandy loam. On the basis of $CaCO_3$ rating suggested by Nachtergaele *et al.* (2009), the soils of the study area were moderately calcareous in nature. All the soil samples were low in organic carbon as per rating suggested by Singh *et al.,* 2007. The data further reveals that most of the soil samples were moderately alkaline in nature. On the basis of EC limit purposed by Muhr *et al.,* (1965) most of the soils under investigation fall in category of normal soils. These soils have low CEC values, on the basis of CEC rating (Hazelton and Murphy, 2007), and this might be due to their coarse texture, low organic matter and presence of high amount of $CaCO_3$. The correlation coefficient between these soil properties shown in Table 5.

3.2 Available micronutrients in soil

The range and mean values of analyzed soil samples given in Table 3. On the basis of critical limit of available iron suggested by Lindsay and Norvell (1978), the soils of Jhunjhunu tehsil except sample no. $\mathbf{P_{24}}$, $\mathbf{P_{27}}$, $\mathbf{P_{39}}$, $\mathbf{P_{55}}$, $\mathbf{P_{60}}$, $\mathbf{P_{65}}$ and $\mathbf{P_{67}}$ (Table 1) are deficient in available iron, while sufficient in available copper except sample no. $\mathbf{P_{20}}$, $\mathbf{P_{48}}$ and $\mathbf{P_{69}}$ (Table 1), whereas, available manganese sufficient in all soil samples**.** On the basis of critical limits of available zinc suggested by Takkar and Mann (1975), 70 per cent soil samples were found deficient, 28.57 per cent samples were marginal and 1.43 per cent samples were sufficient in available zinc. The data clearly indicates that 72.86 per cent soil samples of the study area were found to be sufficient in available boron, as per the critical limit suggested by Berger and Truog, 1939. The correlation coefficient between soil properties and available micronutrients shown in Table 5.

3.3 Micronutrient content in plant

The range and mean values of analyzed plant samples given in Table 4 and correlation coefficient between available micronutrients and their content in plant shown in Table 6.

4. Discussion

4.1 Soil properties

The soils under investigation were mostly loamy in nature, which generally manifests in good structural development, relatively high moisture and nutrient retention capacity and low infiltration rates. Clay minerals influence properties that affect aggregation: surface area, CEC, charge density, dispersivity and expandability, and these in turn affect SOC decomposition rates (Dimoyiannis *et al*., 1998; Schulten and Leinweber, 2000). Soils dominated by variable charge clay minerals such as 1:1 clay and oxides have higher aggregation at lower SOC levels whereas soils with mixed mineralogy clays have higher aggregation at higher SOC (Denef *et al.*, 2002). Sharma *et al.* (2003) reported that the silt plus clay content in soils of Nagaur district of Rajasthan, varies from 7.9 to 21.8 per cent with a mean value 12.9 per cent. Bansal *et al.* (2003) reported that the soils of Ludiana and Jalandhar districts were loamy sand to sandy loam and loamy sand to loam in texture, respectively. Soil structure exerts important influences on the edaphic conditions and the environment (Bronick and Lal, 2005).

The soils of the area under investigation were moderately calcareous in nature (Nachtergaele *et al.* 2009). The accumulation of $CaCO_3$ in soils might be due to semi-arid climatic conditions and drainage problems of the area. This may have facilitated the accumulation of $CaCO_3$ in these soils (Dhir *et al.,* 1979). Based on soil test data, all the soil samples were found low in organic carbon. The low organic carbon content of these soils may be due to poor vegetation and high rate of organic matter decomposition under hyper-thermic temperature regime which leads to extremely high oxidising conditions (Kameriya, 1995). The data further reveals that most of the soil samples were moderately alkaline in nature. Relatively high pH of these soils might be due to medium to high base saturation of soils (Kumar *et al.,* 1997). On the basis of CEC rating (Hazelton and Murphy, 2007), these soils have low CEC values and this might be due to their coarse texture, low organic matter and presence of high amount of $CaCO_3$. This may be because the number of negative charges on soil colloids is reduced with increase in coarseness of the soil particles which may suppress the adsorption of cations on exchange sites.

4.2 Available micronutrients in soil

The availability of micronutrients increased significantly with increase in finer fractions (silt and clay) because these fractions are helpful to improve soil structure and aeration which are favourable conditions for increasing its availability. The available micronutrients were found to increase with increase in CEC of soils due to more availability of exchange sites on soil colloids. Similarly, the availability of micronutrients enhanced significantly with increase in organic matter because: (i) organic matter is helpful in improving soil structure and aeration, (ii) organic matter protects the oxidation and precipitation of micronutrients into unavailable forms and (iii) supply soluble chelating agents which increase the solubility of micronutrient contents. On the other hand, its availability was found to be reduced with increase in pH and $CaCO_3$ content of soils and high pH is responsible for its oxidation. Thus, most readily available form of micronutrients converts into less soluble form after oxidation. Hence, the availability of micronutrients is reduced at higher pH level. Besides, at high pH micronutrients are also precipitated as insoluble form which reduces its availability.

The similar findings reported by Sharma *et al.* (2003) indicated that the available Zn, Cu, Fe, Mn, and B contents in soils of Nagaur district of Rajasthan ranged from 0.1 to 1.7, 0.5 to 3.9, 1.0 to 6.6, 2.7 to 7.2 and 0.2 to 2.0 mg kg^{-1} with the mean values of 0.73, 2.11, 4.32, 5.15 and 0.68 mg kg^{-1}, respectively and then found available Zn, Fe and B were deficient in 46, 51.5 and 26.5 per cent soil samples, respectively, while Cu and Mn were adequate in all the soil samples. Choudhary and Shukla (2004) reported that the available boron content varied from 0.25 to 7.10 mg kg^{-1} and 0.22 to 1.15 mg kg^{-1} with mean values of 1.51 and 0.51 mg kg^{-1} in irrigated and rainfed soils of western Rajasthan, respectively. High content of boron in irrigated soils was due to high boron content in irrigation water. The 48.1 per cent of Indian soils were deficient in DTPA-extractable Zn, 11.2 per cent in Fe, 7 per cent in Cu and 5.1 per cent in Mn (Gupta, 2005). Murthy (2006) also observed that boron deficiency is a global phenomenon, at present, nearly 33 per cent of Indian soils were found deficient in available boron.

Singh (2008) also reported that the analyzed of soil and plant samples had indicated that 49 per cent of soils in India are potentially deficient in Zn, 12 per cent in Fe, 5 per cent in Mn, 3 per cent in Cu, 33 per cent in B. Later on, Sidhu and Sharma (2010) reported that the DTPA-extractable Zn in Trans-Gangetic Plains ranged from 0.11 to 5.08, Cu ranged from 0.22 to 4.72, Mn ranged from 2.9 to 101.2, and Fe ranged from 1.05 to 97.9 mg kg^{-1}. In the Upper Gangetic Plains, the DTPA-extractable Zn ranged from 0.04 to 2.53, Cu ranged from 0.06 to 4.32, Mn ranged from 11.1 to 421.0, and Fe ranged from 3.48 to 90.2 mg kg^{-1}. In the Middle Gangetic Plains, the DTPA-extractable Zn ranged from 0.17 to 8.60, Cu ranged from 0.09 to 7.80, Mn ranged from 3.0 to 155.1, and Fe ranged from 9.22 to 256.7 mg kg^{-1}. In the Lower Gangetic Plains, the DTPA-extractable Zn ranged from 0.04 to 3.46, Cu ranged from 0.21 to 4.38, Mn ranged from 9.54 to 252.2, and Fe ranged from 3.60 to 182.5 mg kg^{-1}.

The Zn, Cu, Fe, Mn and B showed positive correlations with silt plus clay and organic carbon, and negative correlations with pH and calcium carbonate content (Sharma *et al.*, 2003). Sharma *et al.* (2004) investigated that the total content of micronutrients (Fe, Cu, Zn, Mn) increased with an increase in clay and silt and CEC, whereas DTPA-extractable micronutrient increased with an increase in organic carbon content and CEC, and decreased with increasing pH, sand and calcium carbonate content. Moafpouryan and Shukla (2004) observed that the water soluble, non-specifically adsorbed and specifically adsorbed boron were significantly and positively correlated with organic carbon, CEC and clay content. Mathur *et al.* (2006) reported that the DTPA-extractable zinc was significantly and negatively correlated with pH (r = -0.383**), $CaCO_3$ (r = -0.196*), and sand (r = -0.395**) and positively correlated with organic carbon (r = +0.738**), CEC (r = +0.875**) and clay content (r = +0.385**).

Yadav (2008) find out that the available Fe, Mn, Cu and Zn showed positive and significant correlation with organic carbon and also found negatively and significantly correlated with pH and calcium carbonate content of soils. Yadav and Meena (2009) reported that the availability of zinc increased significantly with increase in clay (r = +0.597**), organic carbon (r = +0.896**), EC (r = +0.305*) and CEC (r = +0.527**). On the other hand, the availability of zinc was reduced significantly with an increase in $CaCO_3$ (r = -0.718**) and pH (r = -0.618**) of soil. Sidhu and Sharma (2010) also reported that the available micronutrients (Zn, Cu, Mn and Fe) increased with increase in organic carbon and decreased with increase in sand content, pH, and calcium carbonate.

4.3 Micronutrients content in plant

Sharma and Bapat (2000) reported that the content of zinc in various plant parts increased with increased levels of zinc in soil and the content of Cu and Mn was not influenced with applied Zn. The Fe, Cu and Mn contents in grain and straw of wheat were 80.50 and 137.50; 5.10 and 4.90; 32.1 and 21.3 mg kg^{-1}, respectively. Saini and Gupta (2000) reported that the Fe and Mn content in grain and straw of wheat grown on sandy soils was 59.5 and 304.40; 23.3 and 34.3 mg kg^{-1}, respectively. While, its contents in grain and straw of wheat grown on clay loam soils recorded were 71.66 and 347; 18.8 and 31.0 mg kg^{-1}, respectively. It indicates that uptake of iron depends upon soil on which wheat was grown.

Chahal *et al.* (2005) reported that the Grain yield (g per pot) and total Zn uptake (g per pot) was highest in Entisols followed by Alfisols and Inceptisols. Grain content of zinc was positively and significantly correlated (r = 0.66) with DTPA-extractable zinc in soils. Soil solution plus exchangeable Zn content of the soils was positively and significantly correlated with straw (r = 0.66) and total Zn uptake (r = 0.81). A positive and significant correlation of DTPA-extractable Zn with uptake of Zn showed that the availability of Zn to plant depended upon the amount of DTPA-extractable Zn in soils. The amount of Zn content in both grain and straw was always significantly higher with the application of different levels and modes of chelated-Zn (Zn-EDTA) as compared to $ZnSO_4$ application, being significantly highest content in grain (19.3 mg kg^{-1}) and straw (17.8 mg kg^{-1}) in the treatment where chelated-Zn was applied as two splits during the year 1999 – 2000 (Karak *et al.* 2005).

Shaheen *et al.* (2007) find out that the number of tillers per hill, grain and straw yield of wheat, Zn concentrations and Zn uptake both in grain and straw and Zn concentrations of pre-sowing and post-harvest soils were significantly increased with the application of Zn. Srinivasarao *et al.* (2008) reported that the application of Zn and B significantly increased the uptake of Zn and B in the crop biomass. Kumar *et al.* (2009) investigated that the Cu concentrations in leaves, grain and straw increased significantly with an increase in the level of applied Cu and the applied Cu had significantly reduced the Fe content in wheat leaves. The concentration of Mn in leaves, grain and straw was higher at lower levels of Cu and insignificantly decreased at higher levels of Cu and the application of Cu did not affect the concentration of Zn in the leaves of wheat plants at lower levels of Cu but at higher levels of Cu (2.0 and 2.5 mg kg^{-1}), the Zn concentration decreased significantly.

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Table 1. Description of sampling sites located in Jhunjhunu tehsil of Jhunjhunu district

Sample code no.	Village name	Sample code no.	Village name	Sample code no.	Village name
P_1	Baggar	P_{25}	Dilohi	P_{48}	Lumas
P_2	Bakra	P_{26}	Dolatpura	P_{49}	Luna
P_3	Bajala	P_{27}	Dorasar	P_{50}	Luttu
P_4	Basari	P_{28}	Dulchas	P_{51}	Mahansar
P_5	Bharu	P_{29}	Durana	P_{52}	Malsar
P_6	Bhikhansar	P_{30}	Durjanpura	P_{53}	Mandawa
P_7	Bhimsar	P_{31}	Fatehsara	P_{54}	Mojash
P_8	Bhompura	P_{32}	Gangiasar	P_{55}	Nand
P_9	Bhurasar	P_{33}	Hansasar	P_{56}	Nathasar
P_{10}	Bhutia ka Bas	P_{34}	Hansasari	P_{57}	Niradhanu
P_{11}	Bhurasar Ka Bas	P_{35}	Haripura	P_{58}	Patoda
P_{12}	Bibasar	P_{36}	Hetamsar	P_{59}	Patusar
P_{13}	Bidasar	P_{37}	Indali	P_{60}	Pilani khurd
P_{14}	Binjusar	P_{38}	Indrapura	P_{61}	Rampura
P_{15}	Birmi	P_{39}	Isharpura	P_{62}	Seegda
P_{16}	Bishau	P_{40}	Jaitpura	P_{63}	Seegdi
P_{17}	Budana	P_{41}	Kant	P_{64}	Seetsar
P_{18}	Chakwas	P_{42}	Kishari	P_{65}	Sheshu
P_{19}	Chandva	P_{43}	Kolinda	P_{66}	Shyopura
P_{20}	Churela	P_{44}	Kuharu	P_{67}	Sonasar
P_{21}	Derwala	P_{45}	Kumawas	P_{68}	Suro Ka Bas
P_{22}	Dhanuri	P_{46}	Ladusar	P_{69}	Taai
P_{23}	Dhilsar	P_{47}	Lalpura	P_{70}	Wahid Pura
P_{24}	Dhirasar				

Table 2. Methods of analysis

S. No.	Properties	Procedure	References
I	Soil analysis		
A.	Mechanical analysis	Hydrometer method	Bouyoucos (1962)
B.	Physico-chemical characteristics of soil		
1.	Calcium carbonate	Rapid titration method	Singh *et al.*, (2007)
2.	Organic carbon	Walklay and Black's wet digestion method	Singh *et al.*, (2007)
3.	Cation Exchange Capacity	1N, NH_4OAc method	Jackson (1973)
4.	pH (1:2 soil water suspension)	Using glass electrode pH meter	USDA Hand book No. 60 Richards (1954)
5.	Electrical conductivity (1:2 soil water suspension)	Using the standard precision conductivity bridge	USDA Hand book No. 60 Richards (1954)
C.	Micronutrient Status		
1.	Available Zn, Fe, Cu and Mn	DTPA extract estimated on AAS AA 6300	Lindsay and Norvell, (1978)
2.	Boron	Hot water extraction method on AAS AA 6300	Berger and Truog (1939)
II.	Plant Analysis		
1.	Zn, Fe, Cu, Mn	Tri-acid digestion and estimated on AAS	Lindsay and Norvell (1978)
2.	Boron	Colorimeteric method	Hatcher and Wilcox (1950)

Table 3. Physico-chemical properties and nutrient status of soil

Soil characteristics	Minimum	Maximum	Mean
$CaCO_3$ Per cent	3.90	12.00	8.24
Organic carbon Per cent	0.06	0.43	0.21
pH (1:2 soil water suspension)	8.10	9.20	8.52
EC (dS m^{-1})1:2 soil water suspension	0.20	2.14	1.05
CEC [cmol(p^+) kg^{-1}]	2.40	10.40	6.00
Sand (%)	76.70	90.40	85.91
Silt (%)	1.30	7.50	3.92
Clay (%)	5.20	12.90	8.84
Available Content (mg kg^{-1})			
Iron	1.22	5.87	3.30
Copper	0.17	3.32	1.19
Manganese	2.03	5.67	3.83
Zinc	0.12	1.30	0.51
Boron	0.37	1.51	0.83

Table 4. Micronutrient content in plant (μg g^{-1})

Nutrient	Wheat	Minimum	Maximum	Mean
Iron (Fe)	Grain	87.34	105.45	97.29
	Straw	295.00	322.87	307.27
Copper(Cu)	Grain	6.30	17.87	12.64
	Straw	4.99	11.92	8.27
Manganese (Mn)	Grain	50.30	68.22	59.70
	Straw	41.02	54.93	49.09
Zinc (Zn)	Grain	15.48	25.63	19.39
	Straw	9.30	18.47	13.47
Boron (B)	Grain	44.03	59.00	49.76
	Straw	34.00	47.23	42.05

Table 5. Correlation matrix between soil characteristics

S. No.	Soil characteristics	Sand	*Silt*	Clay	$CaCO_3$	*OC*	pH	EC	CEC	Available micronutrients				
										Fe	Cu	Mn	Zn	B
1.	Sand	1.000	-0.760**	-0.856**	0.521**	-0.585**	0.518**	-0.110	-0.669**	-0.561**	-0.541**	-0.486**	-0.530**	-0.380**
2.	Silt		1.000	0.517**	-0.434**	0.475**	-0.381**	0.044	0.459**	0.248*	0.368**	0.391**	0.381**	0.365**
3.	Clay			1.000	-0.467**	0.551**	-0.467**	0.197	0.717**	0.601**	0.467**	0.420**	0.508**	0.313**
4.	$CaCO_3$				1.000	-0.426**	0.459**	0.041	-0.527**	-0.473**	-0.312**	-0.447**	-0.268*	-0.266*
5.	OC					1.000	-0.445**	0.106	0.510**	0.520**	0.328**	0.446**	0.445**	0.389**
6.	pH						1.000	-0.065	-0.515**	-0.519**	-0.309**	-0.448**	-0.240*	-0.317**
7.	EC							1.000	-0.021	-0.102	-0.097	-0.039	-0.244*	0.032
8.	CEC								1.000	0.573**	0.381**	0.521**	0.441**	0.347**
9.	Available micronutrients Fe									1.000	0.191	0.414**	0.324**	0.208
10.	Cu										1.000	0.219	0.246*	0.140
11.	Mn											1.000	0.334**	0.305*
12.	Zn												1.000	0.377**
13.	B													1.000

*and ** significant at P=0.05 and P=0.01, respectively

Table 6. Correlation matrix between soil characteristics and micronutrient content in plant

S. No.	Soil characteristics	Micronutrients contents in wheat plants									
		Iron		Cu		Mn		Zn		B	
		Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1.	Sand	-0.447**	-0.332**	-0.448**	-0.336**	-0.245*	-0.388**	-0.322**	-0.383**	-0.274*	-0.354**
2.	Silt	0.318**	0.316**	0.292*	0.254*	0.301*	0.257*	0.287*	0.233	0.264*	0.289*
3.	Clay	0.406**	0.221	0.432**	0.262*	0.263*	0.328**	0.195	0.259*	0.260*	0.305*
4.	$CaCO_3$	-0.476**	-0.240*	-0.473**	-0.252*	-0.335**	-0.345**	-0.259*	-0.334**	-0.279*	-0.330**
5.	OC	0.440**	0.323**	0.366**	0.255*	0.246*	0.324**	0.374**	0.415**	0.058	0.376**
6.	pH	-0.607**	-0.266*	-0.140	-0.022	-0.189	-0.379**	-0.286*	-0.288*	-0.306*	-0.368**
7.	EC	0.140	0.080	0.179	0.095	-0.061	-0.069	0.124	0.081	-0.114	0.076
8.	CEC	0.372**	0.275*	0.323**	0.342**	0.149	0.217	0.107	0.168	0.382**	0.306*
9.	Fe	0.627**	0.346**	0.256*	-0.001	0.170	0.244*	0.124	0.287*	0.204	0.353**
10.	Cu	0.106	0.006	0.319**	0.444**	0.004	0.281*	0.230	0.217	0.107	0.002
11.	Mn	0.291*	0.238*	0.265*	0.185	0.337**	0.399**	0.446**	0.365**	0.208	0.252*
12.	Zn	0.310**	0.256*	0.189	0.084	0.287*	0.205	0.368**	0.333**	0.154	0.218
13.	B	0.276*	0.318**	0.188	0.149	0.224	0.336**	0.178	0.128	0.347**	0.394**

* and ** significant at P=0.05 and P=0.01, respectively

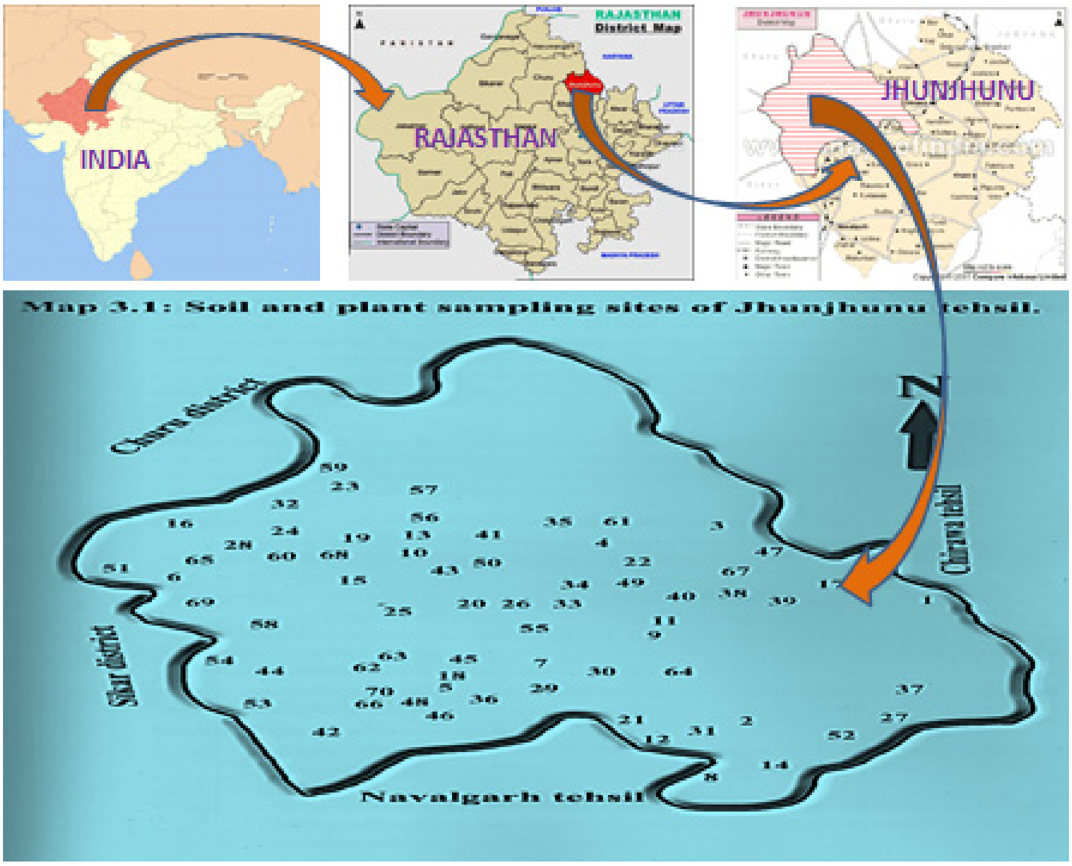

Figure 1. Geographic location of the study area in Jhunjhunu tehsil, district Jhunjhunu, Rajasthan, India

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