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Distribution of DTPA-Extractable Micronutrients and their Relationship with Some Soil Properties in the Soils of Jharsuguda District, Odisha, India

Nirmal Kumar Jena[1*], Antaryami Mishra[2], Amitabh Mahapatra[1] and Mamata Tripathy[3]

[1]*Department of Chemistry, Sambalpur University, Jyoti Vihar, Burla, Sambalpur, Odisha, India*
[2]*Department of Soil Science and Agricultural Chemistry, College of Agriculture, OUAT, Bhubaneswar, Odisha, India*
[3]*Referral Soil Testing Laboratory, Sambalpur, Odisha, India*
**Corresponding author*

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A B S T R A C T

A total of 528 surface soil (0–15 cm) samples, collected from eighty-eight representative villages of all the five blocks of Jharsuguda district in Odisha, were analyzed for distribution of DTPA-extractable Zn, Cu, Fe, Mn and water soluble Boron and to establish their relationship with some soil properties. Based on fertility ratings, pH of soil samples were recorded as extremely acidic to slightly acidic in soil reaction (4.1 – 6.7). Electrical conductivity of the entire study area was found to be normal (< 1 dSm^{-1}). The soil organic carbon was recorded as very low to high (0.09 -1.87%). As per the prescribed critical limits (4.5 mg Fe kg^{-1}), (2 mg Mn kg^{-1}), (0.2 mg Cu kg^{-1}), (0.6 mg Zn kg^{-1}) and (0.5 mg B kg^{-1} of soil), all the soil samples were found to be adequate in Fe (14.32 – 391.06 mg kg^{-1}), Mn (16.12 – 389.80 mg kg^{-1}) and Cu (0.24 – 4.80 mg kg^{-1}) except 16.85% and 73.1% of them were recorded as deficient in Zn (0.28 – 6.94 mg kg^{-1}) and B (0.13 – 1.06 mg kg^{-1}) content respectively. The organic carbon content was observed to have positive and significant correlations with extractable iron (r=0.40**), manganese (r=0.28**), copper (r=0.95**) zinc (r=00.9**) and with water soluble boron (r=0) indicated that no correlation between these two parameters being compared. The soil pH showed a negative and non-significant correlation with extractable iron (r= -0.034), copper (r=-0.04), and zinc (r=-0.03), positive and non-significant correlation with manganese (r=0.042) but positive and significant correlation with boron (r= 0.11*).

Introduction

Micronutrients are important for maintaining soil health and also increasing productivity of crops (Bhanwaria *et al.*, 2011 and Rattan *et al.*, 2009). The soil must supply micronutrients for desired growth of plants and synthesis of human food. Increased removal of micronutrients as a consequence of adoption of high yielding varieties (HYVs) and intensive cropping together with a shift towards high analysis NPK fertilizers has caused a decline in the level of micronutrients in the soil to below normal at which productivity of crops cannot be sustained. The improper nutrient management has, led to emergence of multi-nutrient deficiencies in the Indian soils (Sharma, 2008). Keeping in view the close relationship between soil properties and micronutrient availability, the present study was undertaken to analyze the influence of soil properties on availability of micronutrients for better land use management of Jharsuguda district in Odisha state and to prepare baseline data, as information on these aspects is rather scanty and scattered.

Materials and Methods

Experimental site

Jharsuguda district is situated in the northwestern part of Odisha and is bounded between the 21° 34' North and 22°02' North latitudes and also between 83°25' East and 84°23' East longitudes. It shares its boundary with Sundargarh district in the north, Sambalpur in the east, Bargarh in the south and Chhatisgarh state in the west. Extending over a geographical area of 2081.86 sq. km, it occupies 1.41 % of the area of the state. It receives 1652 mm of average annual rainfall. The district has only one sub-division (Jharsuguda) and five blocks (Jharsuguda, Kirmira, Kolabira, Laikera and Lakhanpur). It is one of the most important industrial districts of the state with a wealth of natural resources (mines and water). The most important rivers flowing through this district are Mahanadi and Ib, the water of which has been most helpful in setting up a number of industries in this district. The Mahanadi reservoir formed by Hirakud Dam is adjacent to Jharsuguda and Lakhanpur block. Jharsuguda district falls under two agroecological zones i.e (i) West Central Table Land Zone and (ii) North Western Plateau. Laikera block falls under North Western Plateau while the rest of the blocks come under West Central Table Zone.

The Minimum and maximum temperature of the district ranges from 26 to 40°C during summer, 16.5 to 30.2° C during winter and 25.3 to 32.5° C during the rainy season. The district receives 1652 mm of average annual rainfall.

Soil Sampling and analysis

The landform of the study area was determined by traversing the area and elevations above MSL of different points were recorded using a GPS instrument (Garmin make; model: 76MAPCSx). Total 528 numbers of composite surface (0–15 cm) soil samples were collected from eighty eight representative villages of all the five blocks which includes 6 samples from each village.

Composite soil samples were collected along with the latitude and longitude of the plots with the help of a GPS instrument. Soils were analyzed for their pH (1:2) (Jackson, 1973), EC (1:2) (Jackson, 1973) and organic carbon (Walkley and Black, 1934) as described by Page *et al.,* (1982). The micronutrients such as Fe, Mn, Cu and Zn were estimated using DTPA solution (Lindsay and Norvell, 1978). Soil B was extracted with hot water and estimated using Azomithene H (Page *et al.*, 1982). All the data were analyzed statistically using the software SPSS (Version 17).

Results and Discussion

Soil reaction

The pH (1:2) of surface soil samples of the entire district was found to be varied in between 4.1 to 6.7 i.e. extremely acidic to slightly acidic with a mean value of 5.43. The type of parent material and leaching of basic cations might be the reason for that. Hence, soil acidity appears to be a major crop production constraint in the study area. Similar findings have also been reported earlier by Dash *et al.,* (2018); Swain *et al.,* (2019) and Mohapatra *et al.,* (2020).

Electrical conductivity

The Electrical Conductivity (1:2) of surface soil samples of the entire study area was found to be less than 1dS m^{-1} (Table 1). Hence, all the soils under the study area are safe for all types of crop production with respect to the soluble salt content.

Soil Organic Carbon (SOC)

SOC value of the distinct ranged between 0.09 to 1.87% with mean value of 0.64 %.This values were categorized under low (below 0.5%), medium (0.5 to 0.75%) and high (>7.5%) and the values under each group were 41.47%, 34.28% and 26.25 % respectively.

The most SOC deficient block was Lakhanpur followed by Laikera. Similar findings was reported by (Mishra *et al.,* 2014 and Maheswar *et al.,* 2018) the low OC content of these soils may be attributed to the poor vegetation and high rate of organic matter decomposition under hyperthermic temperature regime which leads to extremely high oxidizing conditions (Kameriya, 1995 and Bhanwaria *et al.,* 2011).

Available Micronutrients

DTPA Extractable (Fe, Mn, Cu & Zn)

Iron (Fe)

The results revealed that DTPA extractable Fe content varied from 39.24-383.32, 27.56-352.5, 18.46-300.38, 18.94-231.64, 16.12-389.8 mg kg^{-1} with mean value of 145.65, 71.73, 92.19, 87.77, 114.06 mg kg^{-1} in the soils of Jharsuguda, Kirmira, Kolabira, Laikera and Lakhanpur respectively. Considering the critical limits for iron 4.5 mg kg^{-1} all the soil samples under study were found to have high iron levels.

Among the five blocks, soils of Lakhanpur showed highest amount of Fe levels. The high amount of Fe content in these soils might be due to the leaching of exchangeable bases from the surface soils (Hrangbung *et al.,* 2018) and presence of high organic matter content as reported by Sunandana *et al.,* (2019). The DTPA extractable Fe content found to be positively and significantly correlated with organic carbon (r= 0.40**) but negatively and non-significantly correlated with soil pH (r= -0.03). The positive correlation of Fe with soil organic carbon might be due to the formation of the relatively more soluble Fe-organic chelates (Talukdar *et al.,* 2009 and Nisab *et al.,* 2020). The negative correlation with pH indicates that solubility of iron in soil decreases along with increasing pH by the formation of insoluble precipitate. By each unit increase of soil pH in the range of 4 to 9, the solubility of Fe in soil decreases by 1000 fold. (Lindsay, 1979 and Behera *et al.,* 2014). Similar results were also reported by (Yadav *et al.,* 2009 and Nisab *et al.,* 2020).

Manganese (Mn)

The DTPA-extractable Manganese content in the soils of the district were found to have high values. The Mn content varied from 63.4-385.78, 28.09-304.6, 20.72-385.7, 31.58-356.48 and 14.37-391.6 mg kg^{-1} with mean value of 171.05, 134.26, 128.93, 140.56, 97.92 mg kg^{-1} in the soils of Jharsuguda, Kirmira, Kolabira, Laikera and Lakhanpur respectively. The lowest (14.37 mg kg^{-1}) value of Mn was recorded in soils of Kolabira block while highest (391.6 mg kg^{-1}) value of Mn content was observed in soils of Lakhanpur block. So 100% of samples were found to be sufficient in Mn content and the higher content of Mn in these soils might be due to high acidity and chelating of organic compounds released during the decomposition of organic matter. Similar results were reported by Sunandana *et al.,* (2019) and Nisab *et al.,* (2020).

The DTPA extractable Mn content found to be positively and significantly correlated with organic carbon (r= 0.28**). The availability of manganese in these soils increases with increase in organic carbon content of the soil as reported as Sunandana *et al.,* (2019). But negatively and non-significantly correlated with soil pH (r= -0.03) means the available Mn content decreases with increase in soil pH, which may be due to the formation of insoluble higher valent oxides of manganese at higher pH. By increment of each unit of pH in the range of 4 to 9 the solubility of manganese in soil decreases by 100 fold (Lindsay, 1979 and Behera *et al.,* 2014). This result is in close conformity with the findings of Patel *et al.,* (2019).

Table.1 Basic Properties of Surface Soil

Name of the Block	pH			EC (dS m^{-1})			OC (%)		
	Range	Mean	CV(%)	Range	Mean	CV(%)	Range	Mean	CV(%)
Jharsuguda	4.4-6.6	5.34	10.23	0.01-0.50	0.13	65.98	0.17-1.81	0.85	64.30
Kirmira	4.1-6.4	5.48	11.41	0.08-0.28	0.13	41.15	0.17-1.76	0.65	58.32
Kolabira	4.5-6.7	5.29	10.59	0.08-0.28	0.12	35.22	0.09-1.76	0.64	53.71
Laikera	4.5-6.6	5.58	9.19	0.08-0.24	0.13	33.97	0.12-1.87	0.58	67.69
Lakhanpur	4.4-6.7	5.46	9.83	0.08-0.28	0.13	42.33	0.16-1.07	0.47	36.15

CV = Coefficient of Variation

Table.2 DTPA-Fe, Mn, Cu, Zn and B (mg kg^{-1}) of Jharsuguda district.

Name of the Block	DTPA-Fe (mg kg^{-1})			DTPA-Mn (mg kg^{-1})			DTPA-Cu (mg kg^{-1})			DTPA-Zn (mg kg^{-1})			B (mg kg^{-1})		
	Range	Mean	CV (%)	Range	Mean	CV (%)	Range	Mean	CV (%)	Range	Mean	CV (%)	Range	Mean	CV (%)
Jharsuguda	39.24-383.3	145.65	69.28	63.4-385.78	171.05	54.18	0.44 - 6.7	1.97	63.00	0.32 - 6.94	1.22	93.21	0.14-0.95	0.27	64.26
Kirmira	27.56-352.5	118.38	71.73	28.09-304.6	134.26	52.97	0.48-4.42	1.67	54.69	0.32-4.88	1.44	67.71	0.13-0.88	0.40	59.66
Kolabira	18.46-300.38	92.19	62.46	20.72-385.78	128.93	70.91	0.24-4.12	1.60	52.39	0.28-4.58	1.52	54.27	0.13-1.06	0.37	61.94
Laikera	18.94-231.64	87.77	47.44	31.58-356.48	140.58	54.15	0.32-4.8	1.41	64.42	0.32-5.32	1.53	70.30	0.13-0.97	0.44	64.51
Lakhanpur	16.12-389.8	114.06	46.48	14.37-391.6	97.92	91.34	0.38-3.12	1.18	42.82	0.38-4.02	1.41	46.55	0.14-1.06	0.42	53.73

DTPA = Diethylene triamine penta-acetic acid; CV = Coefficient of Variation

Table.3 Correlation between different soil properties and micronutrients.

	pH	EC	OC	Fe	Mn	Cu	Zn	B
pH	1							
EC	0.07	1						
OC	-0.07	-0.03	1					
Fe	-0.03	0.03	0.40**	1				
Mn	0.04	0.07	0.28**	0.63**	1			
Cu	-0.04	-0.02	0.95**	0.40**	0.28**	1		
Zn	-0.03	-0.05	0.90**	0.30**	0.22**	0.88**	1	
B	0.11*	0.06	0	-0.14**	-0.16**	-0.01	0.01	1

*Correlation is significant at the 0.05 level (2-tailed).
**Correlation is significant at the 0.01 level (2-tailed).

Table.4 Rating limits of soil test values used in India.

DTPA-Extractable Micronutrients	Deficient ($mg\ kg^{-1}$)	Sufficient ($mg\ kg^{-1}$)	High ($mg\ kg^{-1}$)
Fe	< 4.5	4.5-9.0	> 9.0
Mn	< 3.5	3.5-7.0	>7.0
Cu	< 0.2	0.2-1.4	>0.4
Zn	< 0.6	0.6-1.2	> 1.2

Copper (Cu)

The DTPA-extractable Cu content in the soil samples of Jharsuguda block varied from 0.44 to 6.7mg kg-1 with mean value of 1.97 mg kg^{-1}; that of soils of Kirmira block varied from 0.48 to 4.42mg kg^{-1} with mean value of 1.67 mg kg-1; that of soils of Kolabira block varied from 0.24 to 4.12 mg kg^{-1} with mean value of 0.1.6 mg kg^{-1}; that of soils of Laikera block varied from 0.32 to 4.8 mg kg^{-1} with mean value of 1.41 mg kg^{-1} and that of soils of Lakhanpur block found to be varied from 0.32 to 3.12mg kg^{-1} with mean value of 1.18mg kg^{-1}. None of the soil samples was detected to be deficient in available Cu with 0.20 mg kg^{-1} as critical limit (Katyal and Rattan, 2003). It was due to rich Cu bearing parent material of the soils. The highest DTPA Cu content was recorded in Jharsuguda block (6.7mg kg-1) whereas the lowest value was recorded in Kolabira block (0.24 mg kg^{-1}) of the district. Available copper content in the soil was found to be positively and significantly correlated with organic carbon (r= 0.95**). Addition of organic matter improves the soil structure and supplies chelating agents which helps in increasing the availability of micronutrients (Sharma *et al.*, 2003). Available copper content was found to be non-significantly and negatively correlated with the pH (r= -0.04).

Zinc (Zn)

The data revealed that DTPA-extractable zinc content in the surface soils of Jharsuguda block varied between 0.32 to 6.94 mg kg^{-1} with a mean value of 1.22 mg kg^{-1}; that of soils of Kirmira block varied between 0.32 to 4.88 mg kg^{-1} with a mean value 1.44 mg kg^{-1}; that of soils of Kolabira block varied between 0.28 to 4.58 mg kg^{-1} with a mean value of 1.52mg kg^{-1}; that of soils of Laikera block varied between 0.32 to5.32 mg kg^{-1} with a mean value of 1.53 mg kg^{-1} and that of soils of Lakhanpur varied between 0.38 to 4.02 mg kg^{-1} with a mean value of 1.41 mg kg^{-1}. Considering the of 0.6 mg kg^{1} (Katyal, 1985) as critical limit for DTPA-Zn, 16.85% of soil samples of the district were investigated to have Zinc deficiency. Maximum deficiency of (25.43%) was observed in Jharsuguda block ; that of Kirmira block (21.87%) of deficiency; that of Kolabira block (14. 7%) of deficiency; that of Laikera block (7.77%) of deficiency and that of Lakhanpur block showed a deficiency of (13.5%). Maheswar *et al.*, (2018) have reported similar results for the soils of Jajpur district of Odisha. Available Zinc content in the soil was found to be positively and significantly correlated with organic carbon (r= 0.9**) whereas negative and non-significant correlation with soil pH (r=--0.03).

Boron (B)

Hot water extractable boron of the district ranged between 0.13 to 1.06 mg kg^{-1} with a mean value 0.38 mg kg^{-1}. The 73.1% soils were deficient in boron and it is the most limiting nutrient in the district considering critical as 0.5mg kg^{-1}. Deficiency is maximum in Jharsuguda block (91.22%) and minimum in Laikera block (61.11%). Parent materials are devoid of B bearing minerals and boron demanding crops like vegetables, pulses, and oilseeds might be leading to B deficiency up to this extent. The mean value of hot water soluble boron content of all the five blocks remained below the critical limits (>0.5 mg kg-1). Similar finding was also reported by Mishra *et al.*, (2016). Available B was found to be positively and significantly correlated with pH (r=0.11*) (Table 3).

The soil analytical data of Jharsuguda district clearly indicates that soil samples were extremely acidic to slightly acidic in soil reaction with normal soluble salt content. The soil organic carbon was recorded as very low to high category. The status of DTPA extractable Fe and Mn were observed to be high to very high category, Cu was sufficient to high level while status of available Zn was detected to be deficient to high level. 16.85% of soil samples of the district were detected to have zinc deficiency and 73.1% soils were boron deficient. From the correlation study it was found that soil pH was negatively and non-significantly correlated with available iron, copper and zinc, positively and non-significantly correlated with available manganese content whereas positively and significantly correlated with hot water soluble boron. Organic carbon content correlated significantly and positively with all the available DTPA-extractible micronutrients. The information of the present study could be useful in micronutrient fertilization strategy in soils of Jharsuguda district, Odisha.

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