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Mapping of DTPA Extractable Micronutrients in Sugarcane Soils of Sudhalagunta Sugar Factory, Andhra Pradesh, India – A GIS Approach

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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

Sugarcane is the most important commercial crop grown in India and plays vital role in agricultural and industrial economy. In Andhra Pradesh, more than 50% of sugarcane is produced from Chittoor district for sugar and jaggery production. Sugarcane is heavy nutrient requirement crop and also removes considerable amount of nutrients through biomass. Continuous application of straight fertilizers, limited use of organic manures as well as non recycling of crop residues causes micronutrient deficiencies in soil. Keeping this in view, the present study was taken up to study the physico-chemical properties and DTPA extractable micronutrients and mapping of these nutrients. Soil samples along with geo reference coordinates were collected and analyzed for physico-chemical properties and DTPA extractable micronutrients (Fe, Mn, Zn and Cu). The digital soil maps for DTPA extractable micronutrients were generated with geo reference coordinates by using GIS approach. The analytical data of soils in Sudhalagunta sugar factory zone, Chittoor district showed that 80% of samples were slightly alkaline in reaction followed by 13% of samples were neutral in reaction. Regarding electrical conductivity, 16% of soils were slightly saline in nature. Among micronutrients, except DTPA-Zn, all cationic micronutrients were existed in above critical

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limit in this factory zone, 11% of soils showed Zn deficiency. Similar trend was noticed in plant Zn content. 18.4% of plant samples showed Zn deficiency. Remaining micronutrients were in sufficient range. Digital maps for DTPA - Fe, Mn, Zn and Cu have prepared.

Keywords: Andhra Pradesh; sugarcane soils; physico-chemical properties; micronutrients; digital maps; GIS approach.

1. INTRODUCTION

"The soil micronutrients related constraints to productivity and other related aspects are being studied since the post green revolution era because of their wide spread deficiencies in soils in majority of the agriculturally progressive states of our country. The Zn deficiency was first noticed in rice in Tarai soils during the 1960's" [1] "later on the deficiency of Zn was observed in sugarcane, rice, chickpea, groundnut etc. on sandy soils" [2] and that of Mn in Wheat – Rice system on light textured soils [3] were reported. The deficiency of Cu and B is emerged out in some pockets.

"Several researchers have indicated that the availability of micronutrients in soils depends on soil physical, chemical and biological conditions in the rhizosphere" [4]. Many of the micronutrient deficiencies brought about by the continuous use of inorganic fertilizers particularly nitrogen, phosphorus and potassium by farmers, limited use of organic manures as well as non-recycling of crop residues and some of the other factors contributing towards exhaustion of micronutrients in soils" [4].

"In the present era of precision forming, the impacts such as fertilizer, crop varieties and management practices are matched precisely with the variability in soil and climatic conditions so that impacts are applied as per the location specific requirements of the crop. The advent of information technology have provided tools like global positioning system (GPS), geographical information system (GIS) which helps in collecting a systematic set of geo-referenced samples and generating the spatial data about the distribution of micronutrients" [5,6]. "The major data generated through remote sensing help in delineating the homogeneous units to decide the sampling size and thereby saving a lot of time. This will also help to monitor the changes in micronutrient status over a period of time as geo referenced sampling sites can be revisited with the help of GPS which is otherwise difficult in the random sampling" [7]. The availability of micronutrients to plants is influenced by certain soil characteristics. Some of the sugarcane growing soils shown micronutrient deficiencies. Hence there is need to identify the micronutrient status and also measures taken for correcting deficiency of micronutrients through efficient sources. In this regard the present investigation was planned with an aim of to study the DTPA extractable micronutrient status with special reference to sugarcane growing soils.

2. MATERIALS AND METHODS

2.1 Sample Collection

The soil samples were collected from Sudhalagunta sugar factory zone (seven mandals) of Chittoor district. The surface soil samples (0-15 cm) were collected before planting of sugarcane for plant crops and after harvesting for ratoon crops. Geo coordinates ALSO recorded for future reference. Plant samples were collected at grand growth stage in the same fields for estimation of nutrient concentration.

2.2 Analysis of Soil Samples

The soil samples were ground, passed through 2-mm sieve and analyzed for physico-chemical properties and DTPA extractable micronutrients (Fe, Mn, Zn and Cu). The soil pH and EC were measured in 1:2.5 soil: water ratio (W/V) suspension using pH meter and EC meter [8]. Soil organic carbon content was estimated by rapid titration method given by Walkley and Black [9]. The DTPA extractable micronutrients were determined as per the method proposed by Lindsay and Norvell [10] and the concentrations of Fe, Mn and Cu were determined using atomic absorption spectrophotometer. The samples were categorized as deficient and sufficient in micronutrients (Fe, Mn, Zn and Cu) as per rating limits given in Table 1.

2.3 Analysis of Plant Samples

"Sugarcane plant samples collected were washed successively with tap water followed by 0.1 *N* HCl, distilled water and de-ionized water. The samples after drying in shade were dried in

hot air oven at 70±2°C and ground in a stainless steel mill and stored for analysis. Plant samples were digested in di-acid mixture (nitric and perchloric acid in the ratio 9:4) and the concentrations of Fe, Mn, Zn and Cu were determined using atomic absorption spectrophotometer" [11]. These plant samples were categorized as sufficient and deficient in particular micronutrient according to the criteria laid down in Table 1.

The descriptive statistics like minimum, maximum and mean standard deviation (SD) for soil properties were computed using the SPSS 20 version. Relationship among the soil properties were established as per the method given by Goulden [12]. The digital soil fertility maps were generated based on geo reference coordinates recorded at sampling sits of field using Arc-info GIS.

3. RESULTS AND DISCUSSION

3.1 Physico-Chemical Properties of Soils

Data pertaining to physico-chemical properties *viz*., pH, EC, organic carbon of sugarcane growing soils is presented in Table 1. The soils of Sudhalagunta sugar factory zone are neutral to strongly alkaline in reaction and non saline to slightly saline nature. Among samples 13% of soils are neutral in reaction, 80% of soils are slightly alkaline and remaining 7% of soils are strongly alkaline in reaction (Table 1). Regard soil salinity 84% of samples are non saline nature, 16% of soils are slightly saline nature. The OC in these soils ranged between 0.17 to 0.58% at the surface with a mean value of 0.40%. There is wide variation in texture. Silt content varied from 0.30 to 26.92%. Clay content varied between 7.18 and 35.16%. The sand content varied from 6.38 to 91.46%.

3.2 DTPA Extractable Micronutrients

A wide range of spatial distribution of DTPA extractable micronutrients was noticed in this sugar factory zone (Table 1). The criteria for assessment of micronutrient status in soils and plants were mentioned in Table 2. The DTPA - Zn in soils varied considerably and ranged from 0.40 to 2.64 mg kg^{-1}. The results are in line with those with those of Talukdar et al., [13] and Mahashabde and Patel [14]. The mean value (1.27 mg kg^{-1}) of DTPA extractable Zn was more than the critical limit of Zn deficiency (0.6 mg kg^{-1}) as suggested by Bansal and Takkar [15,16]. Among the soil samples 11% samples were found to be deficient in DTPA - Zn. The samples falling under sufficient category (more than 0.6 mg kg^{-1}) were further segregated into three subclasses namely sufficient (0.6 to 1.2 mg kg^{-1}), adequate (1.3 to 2.4 mg kg^{-1}) and high (> 2.4 mg kg^{-1}) in DTPA extractable Zn and the corresponding samples in these classes were 45, 42 and 2%, respectively (Table 3). There was a great variation in the DTPA extractable Fe content (4.56 to 32.42 mg kg^{-1}) in the soils of Sudhalagunta sugar factory zone. Similar results were reported by Sharma et al. [17]. The average content of DTPA extractable Fe was 14.55 mg kg^{-1}. All the soil samples were found to be sufficient. The samples sufficient in DTPA Fe were further categorized into four sub classes having limits of DTPA extractable Fe *viz*., 4.5 - 9.0, 9.0 -18.0, 18.0 - 27.0 and >27 .0 mg kg^{-1} and the samples under these categories were found to be 10.5, 70.5, 15 and 14%, respectively (Table 3). The sufficiency of Fe in soils might be due to the amount of iron required by crops is being released by Fe bearing minerals *viz*., hematite and goethite in these soils [18].

The DTPA - Cu of the investigated soils ranged from 0.20 to 2.15 mg kg^{-1} with a mean vale of 0.96 mg kg^{-1} (Table 1). The results are in conformity with those of Arokiyaraj et al., [19]. The data further showed that Cu deficiency was not a problem in these soils as no samples were found to be below the critical limit of 0.2 mg kg^{-1}. The samples falling in sufficiency categories were further categorized into five subclasses *viz*., 0.2 to 0.4, 0.4 to 0.8, 0.8 to 1.6, 1.6 to 3.2 and >3.2 mg kg^{-1}. The responding percentage of samples falling under first four categories was found to be 5.7, 36, 46 and 12.3%, respectively (Table 3). It indicates that majority of soils in Sudhalagunta sugar factory zone are adequate in Cu content. DTPA extractable Mn status of soils ranged from 4.51 to 32.10 mg kg^{-1}, with a mean value of 12.82 mg kg^{-1}. All soil samples are shown above critical limit (4 mg kg^{-1}). These results are in line with Vajantha et al., [20].

Mn deficiency was not observed in sugarcane growing soils because sugarcane is high water requirement crop and crop grown with drip system which provides Mn in reduced conditions and higher availability of Mn to sugarcane [21]. Based on the results, it was found that among DTPA extractable micronutrients, Zn deficiency was observed in soils. Hence, there is a need for Zn fertilization at regular intervals to for correcting Zn deficiency which helps to maximize cane yield and quality. Otherwise, the deficiency

of Zn will gradually become a major constraint to productivity of sugarcane [22].

3.3 Micronutrient Status in Plants

The Zn content in sugarcane leaves varied from 12 to 118 mg kg^{-1} with an average content of 55 mg kg^{-1} considerably 20-100 mg kg^{-1} as the sufficient range in plant samples (Table 4). The Zn deficiency was found in 18.4% samples. Therefore it is advisable that Zn fertilizers should be added in such soils for sustainable sugarcane production. The soils of Pellakur and Naidupet mandal showed more Zn deficiency than other soils. Analysis of both soil and plant samples showed that these soils are deficient in Zn but relatively higher percentage of Zn deficiency was observed in plant samples. The Fe, Mn and Cu content in plant ranged from 40-267, 34-301 and 5.29-18.26 mg kg^{-1}, respectively with a mean value of 128,182 and 12.02 mg kg^{-1}, respectively [23].

3.4 Correlation between Soil Properties and DTPA Micronutrients

Data in table 5 showed the correlation between DTPA extractable micronutrients and chemical properties of soil. Soil pH was significantly negatively correlated with DTPA-Mn. Similar trend was observed in between soil EC and DTPA-Mn. Organic carbon has positively correlated with all DTPA extractable micronutrients (Table 5). These findings are in conformity with those of Nayak et al. [24], Vivekananda et al. [25].

Table 1. Physico chemical properties and DTPA extractable micronutrients in sugarcane growing soils in Sudhalagunta sugar factory zone, Chittoor district, Andhra Pradesh

	pH	EC	OC	DTPA extractable micronutrients			
				Fe	Mn	Zn	Cu
		(dS m^{-1})	(%)	(mg kg^{-1})			
Mandal : Tottambedu							
Min	7.14	0.980	0.17	7.25	6.52	0.62	0.32
Max	8.51	2.844	0.56	26.10	32.10	2.12	2.15
Mean	7.86	1.79	0.34	14.15	16.33	1.26	1.06
Mandal : Srikalahasthi							
Min	7.81	1.420	0.40	7.52	5.24	1.21	0.34
Max	8.30	1.722	0.58	15.55	20.52	1.84	0.94
Mean	8.09	1.508	0.47	10.97	15.48	1.57	0.68
Mandal : K.V.B.Puram							
Min	7.33	0.804	0.28	7.62	20..01	0.40	0.18
Max	8.73	2.996	0.57	32.42	30.57	2.34	2.02
Mean	8.04	1.442	0.44	16.17	12.30	1.12	0.70
Mandal : B.N.Kandriga							
Min	7.01	0.971	0.20	10.24	4.51	0.58	0.58
Max	8.67	2.310	0.58	28.26	18.20	2.58	1.94
Mean	8.02	1.515	0.40	15.57	8.92	1.63	1.13
Mandal : Pellakuru							
Min	8.09	0.768	0.40	8.52	9.54	0.48	0.77
Max	8.72	2.186	0.51	15.02	15.62	0.80	1.05
Mean	8.41	1.476	0.46	11.80	12.23	0.60	0.90
Mandal Sullurupet							
Min	7.33	1.324	0.28	12.04	17.56	0.69	1.16
Max	8.23	1.768	0.36	18.25	26.01	1.02	2.04
Mean	7.81	1.507	0.32	15.51	22.59	0.84	1.57
Mandal Naidupet							
Min	7.20	0.794	0.22	4.56	9.25	0.48	0.74
Max	8.24	1.809	0.52	12.64	21.02	2.64	2.03
Mean	7.86	1.319	0.37	8.14	13.42	1.23	1.09
Overall							
Min	7.01	0.768	0.17	4.56	4.51	0.40	0.20
Max	8.73	2.996	0.58	32.42	32.10	2.64	2.15
Mean	8.00	1.52	0.40	14.55	12.82	1.27	0.96

Table 2. Criteria for assessment of micronutrient status in soils and plants

Micronutrients	Deficient	Soil				
		Sufficient				
		I	II	III	IV	V
Fe (mg kg-1)	<4.5	4.5-9.0	9.0-18.0	18.0-27.0	>27.0	
Zn (mg kg-1)	<0.	0.6-1.2	1.2-2.4	>2.4		
Cu (mg kg-1)	<0.2	0.2-0.4	0.4-0.8	0.8-1.6	1.6-3.2	>3.2
Mn (mg kg-1)	<0.2	>0.2				
Plant						
Micronutrients	Low	Medium	High			
Fe (mg kg^{-1})	<39	40 - 250	>250			
Zn (mg kg^{-1})	<19	20 - 100	>100			
Cu (mg kg^{-1})	<5	5 - 25	>25			
Mn (mg kg^{-1})	<24	25 - 400	>400			

Table 3. Percentage of samples falling in different categories of sufficient ranges of micronutrients

Micronutrients	Deficiency	Sufficient range - Per cent samples under different Categories			
		I	II	III	IV
Fe	-	10.5	70.5	15	4
Zn	11	45	42	2	-
Cu	-	5.7	36	46	12.3

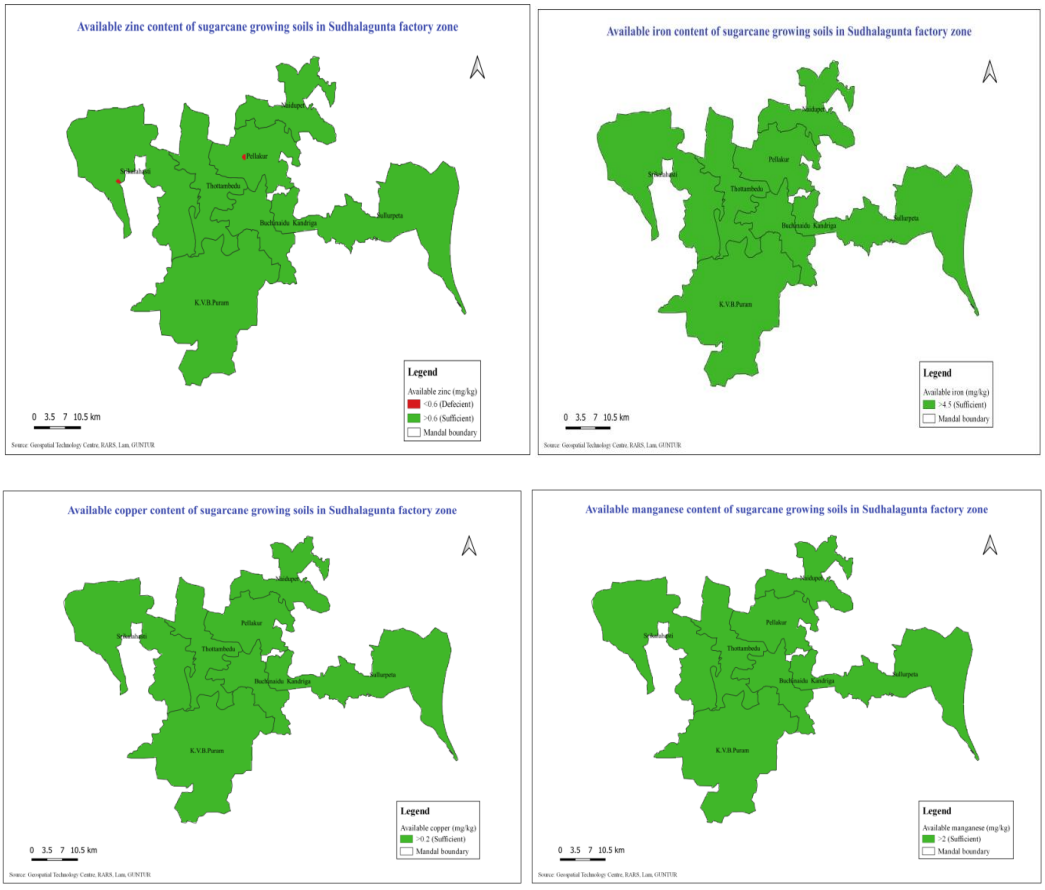

Fig. 1. Map showing sugarcane growing soils in Sudhalagunta factory zone

Table 4. Micronutrient content in sugarcane plant at Sudhalagunta sugar factory zone, Chittoor district, Andhra Pradesh

	Fe content (mg kg^{-1})	Mn content (mg kg^{-1})	Zn content (mg kg^{-1})	Cu content (mg kg^{-1})
Mandal : Tottambedu				
Min	72	74	22	6.24
Max	194	211	81	11.0
Mean	145	129	57	9.32
Mandal : Srikalahasthi				
Min	55	51	34	8.15
Max	216	162	106	10.24
Mean	182	114	71	9.24
Mandal : K.V.B.Puram				
Min	41	59	14	5.29
Max	128	201	85	20.66
Mean	94	s177	48	14.25
Mandal : B.N.Kandriga				
Min	48	38	12	10.25
Max	267	194	118	18.96
Mean	225	126	74	12.25
Mandal : Pellakuru				
Min	60	82	22	7.25
Max	112	244	89	14.26
Mean	90	196	65	11.28
Mandal Sullurupet				
Min	48	52	34	5.99
Max	102	301	78	10.26
Mean	77	218	52	8.92
Mandal Naidupet				
Min	40	34	14	10.66
Max	95	195	55	25.20
Mean	63	122	36	18.26
Overall				
Min	40	34	12	5.29
Max	267	301	118	18.26
Mean	128	182	55	12.02

Table 5. Correlation between DTPA extractable micronutrients and chemical properties of sugarcane growing soils

Soil properties	DTPA - Fe	DTPA - Mn	DTPA - Zn	DTPA - Cu
pH	0.138	-0.285**	0.285	-0.129
EC	0.138	-0.155	0.963	0.047
OC	0.159	0.277	0.963	0.125

4. CONCLUSION

Soil survey and analytical data of Sudhalagunta sugar factory zone, Chittoor district, Andhra Pradesh, India revealed that soils were neutral to alkaline in reaction (80% of samples were slightly alkaline in reaction, non saline nature, low to medium in organic carbon content. Digital maps for DTPA - Fe, Mn, Zn and Cu have prepared by using GIS approach. Regarding micronutrients, except DTPA-Zn, all cationic micronutrients were existed in above critical limit in this factory zone, 11% of soils showed Zn deficiency. Similar trend was noticed in plant Zn content. 18.4% of plant samples showed Zn deficiency. Remaining micronutrients were in sufficient range.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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