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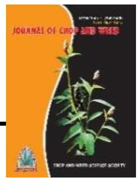

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Nutrient indexing of cationic micronutrients under intensively rice grown Inceptisols

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ABSTRACT

The experimentdelineated micronutrient (Zn, Cu, Fe and Mn) availability in the soils of two intensively rice-cultivated districts falling under the Inceptisols soil order of West Bengal, India. Available Zn in cultivated soils of Nadia varied between 0.03 to 4.06 mg kg^{-1} with anaveragevalue of 1.03 mg kg^{-1}. The major portion of the soil samples (74.9%) falls under low category(0.6-1.2 mg kg^{-1}) while only 2.43% samples were deficient in available Zn in that district. Nutrient index value (NIV) of Zn availabilityin soil of this district was also calculated (NIV=1.24) and found to be low. Availability of Zn in soils of Coochbehar district varried between 0.24 to 4.82 mg kg^{-1} with anaverage value of 1.33 mg kg^{-1}.There also majorpart of the samples was in low (52.8%) and medium (38.5%) category and very few samples (2%) were deficient in available soil Zn. On the other hand, Cu, Fe and Mn availability in all the soil samples were high and the NIV was also high, excepting for available Mn in Coochbehar district. Thus, results revealed that soils of the investigated districts were potential Zn deficient areas. Application of Zn both as soil as well as soil plus foliar might be beneficial in enhancing the yield and quality of crops of these districts.

Keywords:Cationic micronutrients; Nutrient index value; Zinc deficiency; GPS-GIS mapping.

Deficiency of Fe and Zn rank 5th and 11th, respectively among the 20 most important risk factors responsible for the development of illnesses and diseases throughout the world; while in developing countries; according to a WHO report, this deficiency stands in 5thposition among the 10 most important factors (Graham*et al*., 2001).The Indian agricultural soils are becoming a greater deficient of plant nutrients day by day whichwas examined by Shukla *et al.*, 2014 and Shukla *et al*., 2020. Zinc, cobalt, molybdenum, copper, selenium and manganese are out of 25 nutrients required for balancing of life in animal, plant and human, which are considered as micronutrients (Denton-Thompson andSayer, 2022).

The essential micronutrients play the key role as co-factor for different enzymatic activities which is correlated to the metabolic mechanisms of plant such as carbohydrates, nucleic acids, proteins and lipids(Barker and Pilbeam, 2015), and also having important role to get the optimal production with maintaining a satisfactory concentration in economical part of plant (Rastogi*et al*., 2014). The Zn deficiency among the world population, on an average, varied between 4-37% amongthe different countries which is almost one-third of world's population(Hotzand Brown, 2004) and these deficiencies may cause severe health problems like impairments of physical growth, inefficient immune system development and disabilities in learning,

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Which combinely increases risk of infections, DNA damage and ultimately development of serious health disease like cancer (Hotz and Brown, 2004). Because of the report of widespread occurrence of micronutrient deficiency from different parts of the country which limiting crop production and have received a great deal of importance in crop production during the recent years. Significant response of many crops to micronutrient fertilization has also been reported by different investigators from almost all the states in the country (*Halder et al.*, 2022). Micronutrient deficiencies in soils not onlylimit crop production, but they also have negative effects on human nutrition and health, thus gaining an importance of its proper delineation in intensively cultivated areas of the region.Micronutrients distribution may diverse through the different soil profiles based on their developmentfromdissimilar parent materials and agro-climatic situations. Cationic micronutrients (Zn, Cu, Fe and Mn) requirement is very low for growth and development of crop. Micronutrients deficiency is becoming prominent due to intensive crop cultivation practice by adopting high yielding varieties of crops leading to loss of crop yields as well as quality of crops (Singh, 2009). The Indian soils are of deficient in essential micronutrients in districts, states and different Agro-ecological zones across the country (Shukla *et al*., 2020) leading to suffering from micronutrient deficiency that reducing the productivity and degrading the food quality.

So, delineation of available quantities of these micronutrients with frontier technologies *viz.,* use of global positioning system (GPS) and geographical information system (GIS) has gained a prime importance in Indian agriculture and would be useful to give ready reckoner to farmers for optimization of management of these high value nutrients to maintain yield and quality of crops. Keeping the above in view, the study was undertaken in two intensively rice cultivated districts *viz.*, Nadia and Coochbehar falling under Inceptisols soil order to delineate and to prepare GPS-GIS based delineation map of available Zn, Cu, Fe and Mn.The results would be immensely helpful in deciding the micronutrients fertilization of rice crops in the sites of Nadia and Coochbehar districts of West Bengal, India.

MATERIALS AND METHODS

Nutrient indexing of available Zn, Cu, Fe and Mn in cultivated soils of Nadia and Coochbehardistricts, West Bengal, Indiawas calculated and presented. The soils of the studied districts arefalling in the soil order Inceptisols. The NIV was calculated after collecting and analysing soil samples of 247 numberfrom Nadia and 252 number from the Coochbehar district. Grid sampling pattern was followed while collecting the soil samples by maintaining a grid of4.0 km for Nadia and 3.7 km for Coochbehar district with the use of GPS (GARMIN GPS Version *etrex*) after harvesting of kharif rice i.e., during the month of November. The existing block level maps from Survey of India were procured from the Regional Office of Survey of India, Kolkata, West Bengal and used as geo-referencing. During soil sampling procedure, it was tried and more than 90% of the cases it was maintained to take the soil samples from predominant rice-based cropping system where more than 200% cropping intensity was followed. The sampling process covered 14 and 11 developmental blocks of Nadia and Coochbehar district, respectively. GPS-GIS based delineation mapsfor the available Zinc, Copper, Iron and Manganese status insoils of two districts were made using *Arc*GIS software.

Soil samples, which were collected from different districts, were gone under the following procedure of drying, grounding and screening through 2mm nylon sieve within one day after collection and kept in plastic container made with polypropylene. Thereafter, these samples were analysed for physico-chemical properties *viz*., soil pH and organic carbon as well as DTPA-extractable Zn,Cu,Fe and Mn contents. The collected samples were differentiated as deficient, marginal (low), adequate (medium) and high by their availability within soils system (Singh, 2009) as stated in Table 1. Nutrient index value (NIV) for soils of individual district was calculated using Parker's equation (1951):

$$\text{Nutrient index value} = \frac{N_1X_1+N_mX_2+N_hX_3}{N_1+N_m+N_h},$$

where, N_l, N_m and N_h are the number of soil samples falling in the category of low, medium and high nutrient status and are given weightage of 1, 2 and 3 respectively. Three different classes are assigned to soil on the basis of nutrient index value as described: Low <1.67, Medium 1.67-2.33, High >2.33 as modified by Ramamoorthy and Bajaj (1969).

RESULTS AND DISCUSSION

Soil pH

Results (Table 2) revealed that soil pH of the district Nadia ranged from 5.26 to 8.30 with an average of 7.32. Almost 24.7% of samples were in between the pH range of 6-7 (slightly acidic); whereas, 65.6% recorded a pH range of 7-8 (slightly alkaline). The survey data also indicated that the maximumsoil pH was underthe block Ranaghat-I, while minimum was under Chapra block. Soil pH of Coochbehar (Table 2) ranged from 4.91-7.78 with anaveragevalue of 5.64. It was noticedthat 88.3% of the survey samples were under pH between 5 and 6 (moderately acidic) and the rest samples of 10.5% were between pH 6 and

7 (slightly acidic). So, from the survey report it was clear that major portion of the samples were under acidic in nature, may be due to the loss of basic cations from the soil surface because of high rainfall (average annual rainfall 1236-3000 mm). Availability of zinc decreases with increasing soil pH and in general, neutral and calcareous soils are deficient in pH induced Zn, though few showed exceptional status due to their availability increased form Zn chelation. The trace elements availability is controlled through various soil reactions such as precipitation, adsorption, desorption, ion exchange, inorganic and organic ligands, acid base equilibria and solid dissolution (Dhaliwal *et al*., 2019).

Soil organic carbon

Results revealed that organic carbon in soilsamples of Nadia varied between 0.15 to 1.79% with an averagevalue of 0.79% (Table 2). There was 42.9% samples which fall under low category (<0.75%), and 56.3% was categorized as medium (0.75-1.50%). It is clear from the survey data that organic carbon in Nadia soil belongs under low to medium range because of high intensive crop cultivation practices year after year in this district.

There was a variation of 0.39 to 1.62% organic C content in Coochbehar soil with an averagevalue of 0.96%(Table 2). Here, almost all the soil samples are in the category of medium (0.75-1.50%) which might be due to low temperature and high rainfall in this district(Singh*et al*., 2021).The soil organic carbon enhances the availability of essential cation micronutrients and also reduces the toxicity by chelation (Stevenson, 1991). The organic matter improved in plant nutrients uptake from the soil (Kumar *et al.*, 2020).

Available Zn status of soil

Results of available Zn content in soils of Nadia district ranged from 0.03 to 4.06 mg kg^{-1} with a mean value of 1.03 mg kg^{-1} (Table 5). Highest available Zn content was found in Ranaghat-I and Tehatta-I block followed by Haringhata, Chakdaha and Nakashipara respectively (Table 4). Results also demonstrated that major portion of the soil samples (74.9%) were in low category (0.6-1.2 mg kg^{-1}) and only 2.43% samples were deficient in available soil Zn. NIV of Zn availability in soil of this district was 1.24, showed that Zn availability of Nadia is under low category (Table 5). The index value of different nutrients calculated from the 14 blocks soil samples of Tiruchirapalli district (Tamil Nadu) suggested that the value was under the range of low to high for different study blocks (Amar and Shanmugasundaram, 2020).The low Zn content of Nadia district may be due to high cropping intensity as well as comparatively higher pH of soils. GPS-GIS based delineation map of this district is presented in Fig. 1.

Available Zn content in the soil samples of Coochbehar district revealed that Zn content ranged between 0.24 to 4.82 mg kg^{-1} with a mean value of 1.33 mg kg^{-1} (Table 5). Thus the soil samples of Coochbehar district also belongs under the following categories: low (52.8%), medium (38.5%) and few samples (2%) are deficient in Zn. NIV calculation (=1.52) also showed that Zn availability status of Coochbehar district falls under medium category (Mistry *et al.*, 2022; Vikas *et al*., 2020). Block wise representation of available soil Zn content also showed that out of 11 blocks, only 3 blocks were under low category and 8 blocks were under medium category as per the NIV values (Table 4). GPS-GIS based delineation map of this district is presented in Fig. 2.

Available Cu status of soil

The Cu availability in soil samples of Nadia district ranged between 2.0 to 17.7 mg kg^{-1} with an average of 8.9 mg kg^{-1}. Data obtained under survey showed that Cu content was high (>1.2 mg kg^{-1}) in all the soil samples which is also corroborated with the NIV value (3.0) for this district (Table 5).

The available Cu content (Table 5) ranged from 0.12 to 13.5 mg kg^{-1} with an average value of 3.65 mg kg^{-1} in soil samples from Coochbehar district. Like Nadia, here also available Cu status was high in almost all the soils. Its NIV value is also in the category of high (2.88). Block wise representation of Cu availability in soil of Coochbehar district also showed that all the eleven blocks of this district recorded a high value of its amount which was supported by high magnitude of NIV (Table 5). GPS-GIS based delineation map of both these districts are presented in Fig. 3 and 4.The mapping was done according to availability in soil and reported sufficiency and deficiency of cationic micronutrients (Mistry *et al.*, 2022; Vikas *et al*., 2020).

Available Fe status of soil

Fe availability in soil samples of Nadia district demonstrated that its magnitude varied between 6.9 to 293.7 mg kg^{-1} with an average value of 92.3 mg kg^{-1}. Results also displayed that almost all the samples (96%) were high in available Fe content. NIV of available soil Fe of this district is 2.96 (Table 5).

Soils of Coochbehar district also recorded a high value of available Fe content in soil and its magnitude varied from 23.1 to 435.8 mg kg^{-1} with an average value of 150.7 mg kg^{-1}. From the dataset, it was noticed that almost every samples (almost 100%) were high in available Fe content and its NIV is 2.99 (Table 5). Block wise representation (Table 4) of available Fe content in soil of Coochbehar district revealed that all the eleven blocks were high in its content as per the NIV values. GPS-GIS based delineation map of both these districts are presented in Fig. 5 and 6. The mapping of cationic micronutrients availability in soil was effective to identifying the sufficiency and deficiency of micronutrients in soil (Vikas *et al*., 2020).

Available Mn status of soil

Mnavailability in the soilsamples of Nadia district varied from 3.5 to 104.9 mg kg^{-1} with an average value of 21.4mg kg^{-1}. Results also showed that among all the soil samples, most of the soil (65%) recorded a high value in its content and rest of the samples (35%) was adequate. NIV (Table 5) calculation for its amount in this district also recorded a high value (2.65) which is corroborated with aforesaid view. GPS-GIS based delineation map of this district was presented in Fig. 7.

Available Mn content in soils of Coochbehar district, on the other hand, showed that about half of the samples (54%) were in medium category and the rest was under the category of high and marginal. Its magnitude varied between 1.2 and 90.7 mg kg^{-1} having an average value of 11.6 mg kg^{-1} ,where a few samples were deficient (2.8%) in its amount. NIV calculation (Table 5) of its amount in this district revealed a value (2.02) of medium category which has further strengthened the above view. Block wise representation of its content also revealed that only one block was under low NIV and the other ten blocks were under medium NIV category (Table 4). So, from the results it can be opined that available Mn content in soils of Coochbehar district is under medium NIV category. GPS-GIS based delineation map of this district is presented in Fig. 8. The mapping was completed based on availability in soil and reported sufficiency and lacking of cationic micronutrients (Mistry *et al.*, 2022; Vikas *et al*., 2020).

Table 1: Categorization of available micronutrients status in soil

Elements	Soil status (mg kg^{-1})			
	Deficient	Marginal (Low)	Adequate (Medium)	High
Zn	<0.6	0.6-1.2	1.2-2.4	>2.4
Cu	<0.2	0.2-0.4	0.4-1.2	>1.2
Fe	<4.5	4.5-9.0	9.0-27.0	>27.0
Mn	<2.0	2.0-4.0	4.0-16.0	>16.0

Table 2: Block wise pH and organic carbon content (%) in soil samples of Nadia and Cooch Behar district of West Bengal

Nadia District			Cooch Behar district		
Name of the block	pH	OC (%)	Name of the block	pH	OC (%)
Tahatta I	7.44	0.95	Mathabhanga II	5.58	0.97
Tahatta II	7.28	0.71	Mathabhanga I	5.53	0.98
Kaliganj	7.38	0.79	Sitalkuchi	5.55	0.95
Nakashipara	7.10	0.83	Sitai	5.62	0.98
Chapra	6.97	0.81	Mekhliganj	5.52	0.97
Krishnanagar II	7.62	0.78	Dinhata I	5.55	0.88
Krishnanagar I	7.33	0.72	Dinhata II	5.94	1.00
Krishnaganj	7.07	0.79	Tufanganj II	5.57	0.92
Hanskhali	7.53	0.79	Coochbehar I	5.91	0.90
Santipur	7.16	0.74	Coochbehar II	5.61	0.95
Ranaghat I	7.69	0.88	Tufanganj I	5.57	1.06
Ranaghat II	7.25	0.81			
Chakdah	7.40	0.87			
Haringhata	7.26	0.79			

Table 3: Block wise Zn, Cu, Fe and Mn concentration (mg kg^{-1}) of soil samples as well as NIV of Zn, Cu, Fe and Mn of Nadia district of West Bengal

	Zn				Cu				Fe				Mn			
Name of the block	Range	Mean	SD	NIV	Range	Mean	SD	NIV	Range	Mean	SD	NIV	Range	Mean	SD	NIV
Tahatta I	1.36-1.45	1.4	0.1	2.00	10.4-15.0	12.36	2.0	3.00	121.1-205.8	164.4	34.6	3.00	16.6-35.2	25.7	7.6	3.00
Tahatta II	0.69-1.98	1.0	0.3	1.33	2.1-15.4	7.57	3.2	3.00	13.3-172.0	87.0	50.7	2.87	12.4-30.7	19.3	4.9	2.80
Kaliganj	0.61-1.26	0.8	0.2	1.08	6.2-14.7	8.56	2.2	3.00	41.3-252.2	102.7	58.0	3.00	7.6-34.2	18.2	7.4	2.54
Nakashipara	0.61-1.58	1.1	0.3	1.33	6.6-12.6	9.69	1.9	3.00	33.4-263.5	112.5	65.5	3.00	13.5-34.9	24.7	7.1	2.92
Chapra	0.66-1.40	1.0	0.3	1.22	7.0-17.7	10.31	3.4	3.00	42.4-267.6	106.3	67.5	3.00	14.8-35.8	22.4	7.4	2.78
Krishnanagar II	0.66-1.08	0.9	0.1	1.00	5.1-13.5	8.38	2.1	3.00	23.2-166.2	74.9	39.1	2.94	11.0-23.4	17.3	3.1	2.71
Krishnanagar I	0.03-1.63	0.9	0.3	1.17	8.3-13.4	8.13	2.5	3.00	17.3-164.0	73.5	40.8	2.93	9.3-104.9	24.9	18.9	2.63
Krishnaganj	0.66-1.31	0.9	0.2	1.25	8.8-13.0	10.37	1.2	3.00	47.8-150.7	82.3	35.0	3.00	8.6-35.4	20.6	9.3	2.75
Hanskhali	0.59-4.06	1.1	0.9	1.21	4.1-12.9	8.32	2.5	3.00	45.2-204.5	95.5	43.7	3.00	3.6-30.0	15.5	7.4	2.50
Santipur	0.06-1.88	1.0	0.4	1.28	2.9-16.1	9.06	3.3	3.00	19.1-263.9	85.0	62.4	2.97	12.7-79.6	26.8	14.1	2.84
Ranaghat I	0.78-2.93	1.4	0.6	1.67	7.7-16.3	9.78	2.6	3.00	59.0-155.1	83.6	30.5	3.00	9.5-27.5	16.8	6.1	2.44
Ranaghat II	0.61-1.79	0.9	0.3	1.17	2.0-10.5	7.58	2.2	3.00	31.0-293.7	115.2	65.6	3.00	3.5-37.9	16.7	9.9	2.28
Chakdah	0.60-2.68	1.1	0.4	1.23	3.8-15.5	9.26	2.7	3.00	6.9-211.7	89.5	51.2	2.93	5.8-72.4	24.0	14.7	2.73
Haringhata	0.64-2.21	1.1	0.4	1.37	4.4-17.4	9.47	3.0	3.00	33.8-226.2	102.1	46.8	3.00	5.7-34.3	18.1	8.9	2.41

Table 4: Block wise Zn, Cu, Fe and Mn concentration (mg kg^{-1}) of soil samples as well as NIV of Zn, Cu, Fe and Mn of Coochbehar district of West Bengal

	Zn				Cu				Fe				Mn			
Name of the block	Range	Mean	SD	NIV	Range	Mean	SD	NIV	Range	Mean	SD	NIV	Range	Mean	SD	NIV
Mathabhanga II	0.8-2.9	1.51	0.6	1.77	1.7-6.3	3.7	1.3	3.00	81.9-435.8	206.9	93.6	3.00	2.0-31.4	12.8	8.4	2.23
Mathabhanga I	0.5-1.9	1.06	0.3	1.22	0.3-6.2	3.0	1.4	2.85	67.8-270.6	132.7	50.3	3.00	2.0-28.0	9.3	6.7	1.89
Sitalkuchi	0.6-2.7	1.27	0.6	1.50	0.3-4.0	1.6	0.9	2.50	41.3-274.2	136.1	67.9	3.00	1.8-21.1	6.5	5.3	1.64
Sitai	0.6-1.3	0.83	0.3	1.25	0.1-4.1	2.4	1.7	2.50	87.1-214.5	155.2	52.3	3.00	3.2-5.0	3.9	0.8	1.25
Mekhliganj	0.2-2.2	0.91	0.4	1.11	0.1-10.9	2.6	2.8	2.42	34.2-251.0	106.8	54.0	3.00	1.2-21.2	6.8	5.1	1.68
Dinhata I	0.7-3.2	1.41	0.8	1.55	0.8-6.0	3.5	1.4	2.95	99.3-262.2	170.9	46.8	3.00	2.4-32.4	10.7	8.5	2.05
Dinhata II	0.7-3.7	1.29	0.6	1.44	1.4-13.5	4.4	2.8	3.00	49.8-333.4	179.7	65.2	3.00	3.0-90.7	17.9	22.3	2.20
Tufanganj II	0.8-2.2	1.29	0.4	1.53	0.6-9.1	3.9	2.0	2.91	55.5-286.9	148.6	54.3	3.00	2.3-34.8	9.2	8.8	1.88
Coochbehar I	0.7-4.8	1.27	0.7	1.40	0.2-8.3	3.9	1.9	2.93	74.9-263.4	131.9	37.6	3.00	1.5-33.1	12.7	8.9	2.17
Coochbehar II	0.9-3.8	1.63	0.7	1.96	1.8-11.2	5.2	2.6	3.00	46.6-292.9	152.3	61.0	3.00	3.0-33.5	12.7	9.8	2.22
Tufanganj I	0.8-4.4	1.58	0.7	1.66	1.2-8.4	3.7	2.0	2.97	23.1-256.3	142.2	56.4	2.97	1.7-65.1	14.6	15.1	2.09

Table 5: Summary of the available status of Micronutrients in the soils of Nadia and Cooch Behar District

Element	Range (mg kg^{-1})	Mean (mg kg^{-1})	SD	No. of samples falling in the category of				NIV
				Deficient	Marginal	Adequate	High	
Nadia District								
Zn	0.032-4.06	1.029	0.405	6	185	53	3	1.24
Cu	1.98-17.72	8.89	2.747	0	0	0	247	3.00
Fe	6.86-293.68	92.29	52.811	0	1	7	239	2.96
Mn	3.52-104.86	21.38	12.12	0	2	83	162	2.65
Cooch Behar District								
Zn	0.24-4.82	1.33	0.63	5	133	97	17	1.52
Cu	0.12-13.52	3.65	2.19	3	4	16	229	2.88
Fe	23.14-435.82	150.70	63.19	0	0	1	251	2.99
Mn	1.24-90.7	11.57	11.61	7	48	138	59	2.02

NIV: Low <1.34, Medium 1.34-2.33, High >2.33.

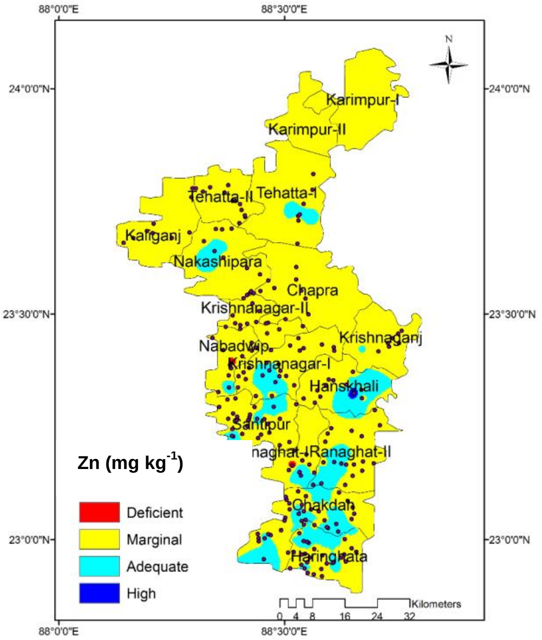

Fig. 1:GPS-GIS based Zn delineation map of the district Nadia

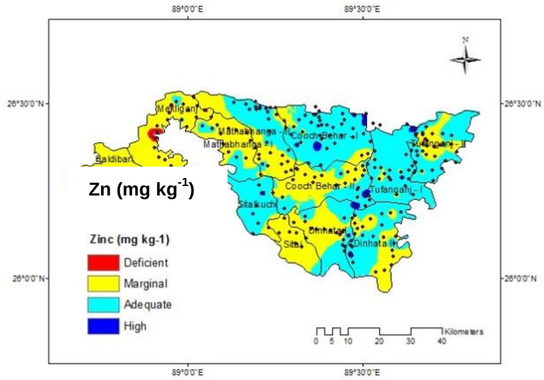

Fig. 2:GPS-GIS based Zn delineation map of the district Cooch Behar

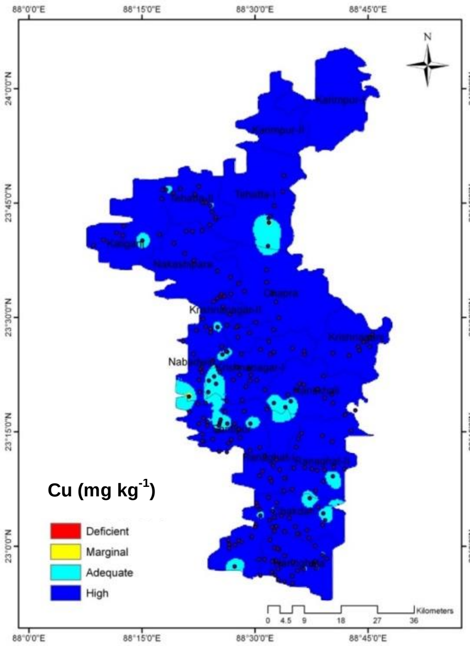

Fig. 3:GPS-GIS based Cu delineation map of the district Nadia

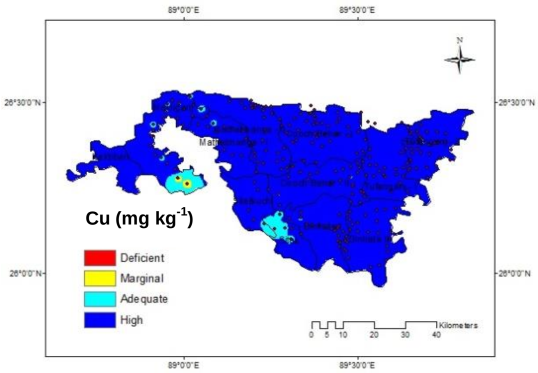

Fig. 4:GPS-GIS based Cu delineation map of the district Cooch Behar

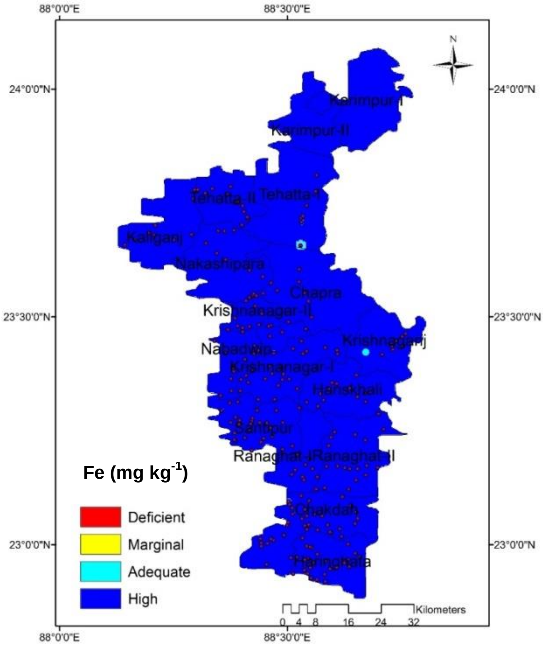

Fig. 5:GPS-GIS based Fe delineation map of the district Nadia

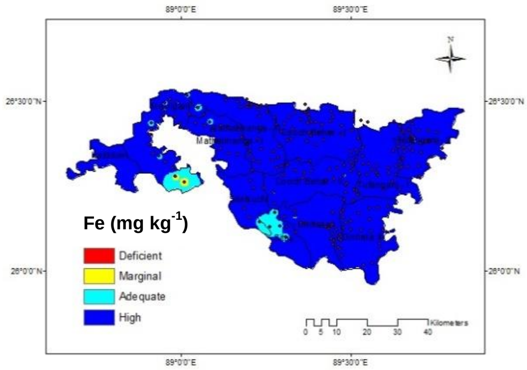

Fig. 6:GPS-GIS based Fe delineation map of the district Cooch Behar

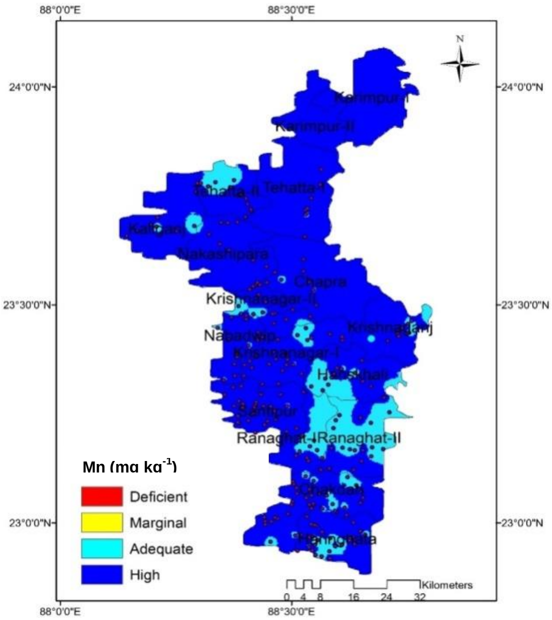

Fig. 7:GPS-GIS based Mn delineation map of the district Nadia

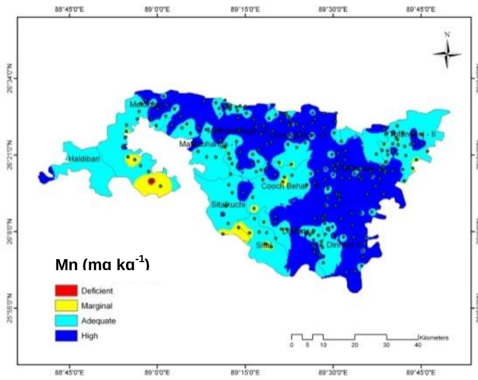

Fig. 8: GPS-GIS based Mn delineation map of the district Cooch Behar

CONCLUSION

Information on available Zn status in the intensively cultivated areas of the state of West Bengal is not adequate. But these areas are of potential Zn deficient. Attempts have, therefore been made in the present study to know the status of Zn availability in soils of two representative districts, namely Nadia and Coochbehar of the state, where intensive agriculture is practised. Results revealed that available Zn content in soils of Nadia varied between 0.03 to 4.06 mg kg^{-1} with an average value of 1.03 mg kg^{-1}. It was also noticed that major portion of the samples (74.9%) were under low category (0.6-1.2 mg kg^{-1}),while only 2.43% samples were deficient in Zn. Zn availability in the soil samples of Coochbehar district varied between 0.24 and 4.82 mg kg^{-1} with an average value of 1.33 mg kg^{-1}. The results also revealed that the samples mainly fall under low (52.8%) and medium (38.5%) category,while only 2% samples are deficient in Zn. Survey reports showed that Cu, Fe and Mn availability were high in almost all the soil samples and NIV is also high excepting for available Mn content in Coochbehar district. These micronutrients (in particular Zn and Mn) are becoming deficient day by day due to intensive cultivation of high yielding varieties of crops leading to loss of crop yields as well as quality of crops. So, delineation of available quantities of these micronutrients with frontier technologies could help the planners of the State Govt. as well as Agricultural Extension workers/scientists for recommendations in predominant rice based cropping systems followed in the studied districts of the State.

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