International Journal of Environment and Climate Change

Volume 14, Issue 2, Page 915-922, 2024; Article no.IJECC.113211
ISSN: 2581-8627
(Past name: British Journal of Environment & Climate Change, Past ISSN: 2231–4784)

Availability of Cationic Micronutrients in Soils of Bankura District of West Bengal, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJECC/2024/v14i24005

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/113211

Original Research Article

Received: 15/12/2023
Accepted: 21/02/2024
Published: 27/02/2024

ABSTRACT

The goal of the current investigation was to evaluate the state of DTPA-extractable cationic micronutrients (Zn, Fe, Mn, and Cu) concerning some properties of soils of Bankura district, West Bengal. Ninety-nine soil samples in all (0-15 cm) were collected from 9 blocks (viz., Bankura II, Onda, Bisnupur, Barjora, Raipur, Sarenga, Bankura I, Gangajalghati, and Chatna) of the Bankura district of West Bengal. Using standard analytical techniques, these soil samples were examined for a variety of soil parameters, including DTPA-extractable Zn, Fe, Mn, and Cu, pH, electrical conductivity (EC), oxidizable organic carbon (OC) content, and particle size distribution. The research area's soil is characterized by sandy clay loam to sandy loam in texture, with few samples having loamy sand texture and strongly acidic to neutral in reaction. The EC was found to be very low (<1.0 dSm^{-1}), indicating the safe limit for soils whereas the value of OC was low to medium. The status of DTPA-extractable Zn ranged between 0.45 to 3.47 mg kg^{-1} which was deficient to sufficient in category. The DTPA-extractable Fe, Mn, and Cu showed variation from 6.52 to 56.27, 4.73 to 26.81, and 0.51 to 5.29 mg kg^{-1}, respectively which were in a higher range. Soil pH showed

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a substantial positive correlation with available Zn and Mn contents in soil but not with Cu and Fe. Organic carbon correlated significantly and positively with available Fe whereas non-significantly with available Zn and Mn.

Keywords: Distribution; zinc; copper; iron; manganese; soil characteristics; co-relationship.

1. INTRODUCTION

Soil fertility is the soil's inherent ability to provide sufficient quantities and proportions of essential plant nutrients for optimum growth and development of specified plants. Macronutrients and micronutrients are important soil elements that control soil fertility. Copper (Cu), manganese (Mn), zinc (Zn), and iron (Fe) are indispensable for the best possible growth of plants because they are involved in a wide range of physiological activities and enzymes, such as gene expression, protein, chlorophyll, and secondary metabolite biosynthesis, carbohydrate and lipid metabolism, stress tolerance, and more [1,2]. Furthermore, Zn is involved in the synthesis of indole acetic acid, metabolism of gibberellic acid and synthesis of RNA; Cu enhances the fertility of male flower and also increases plant's disease resistance. Manganese, however, is necessary for both nitrogen metabolism and photosynthesis. Despite having the same agronomic importance as macronutrients, micronutrients have not often been applied to soil in conjunction with conventional fertilizer, which has caused a nutritional imbalance in soils. Furthermore, in intensive cropping, the use of high-analysis primary nutrient fertilizers, the use of varieties having high yields, the loss of micronutrients, and the reduced usage of farmyard manure are a few factors accelerating the depletion availability of soil micronutrients. Micronutrient problems, which are currently only local, could very likely get worse and spread more quickly soon. Micronutrient deficiencies can be primarily due to low cumulative level) or secondarily due to the soil conditions that reduce the supply to micronutrients to crop plants [3].

Keeping these in mind in addition to the lack of data on the content of micronutrients to determine whether the soils in the Bankura district are becoming toxic or lacking in micronutrients, a complete study was designed to obtain the content of micronutrients and their interrelationship with physicochemical properties in soils of Bankura district, West Bengal, which will be useful to recommendation of fertilizers for sustainable crop yield.

2. MATERIALS AND METHODS

2.1 Study Area

The soils of nine distinct blocks in West Bengal's Bankura area served as the study's materials. The district covers a total area of 6882 km^2 which is generally lower in fertility because of the existence of lateritic soils and undulating topography. This district shares a border with Midnapore and Hooghly in the East, Purulia in the West, Burdwan in the North, and Purulia in the South. The district has a hot and humid climate with a wide range of temperatures. Summer is characterized by high heat and high humidity, with maximum temperatures on average daily ranging from 26°C to 39°C. Winters are typically cold and dry, with average winter temperatures hovering around 15°C. In comparison to the western areas, the eastern portions receive more rainfall. The annual average rainfall ranges between 1300 cm to 1400 mm. The relative humidity is generally high throughout the year. About 78 percent of annual rainfall mainly occurs during the monsoon month (June to September).

2.2 Soil Sampling

A total of 99 soil samples were collected at a depth of 0-15 cm (surface soil) from the farmer's field after harvesting rice from 9 blocks viz., Bankura I, Bankura II, Onda, Bisnupur, Raipur, Sarenga, Gangajalghati, Barjora, and Chatna of Bankura district of West Bengal. After being allowed to air dry in the shade, the soil samples were ground into a powder using a wooden pestle and mortar, sieved through a 2 mm screen, and preserved in plastic container labelled appropriately for later examination.

2.3 Soil Analysis

Using a sophisticated pH meter, soil samples were examined for soil reaction (pH) in with soil : water suspension of 1:2.5 [4]. According to Jackson's guidelines [4], an electrical conductivity (EC) meter was used to measure the EC. Oxidizable organic carbon (OC) content was determined by the Walkley and Black [5] procedure. Following the guidelines of Bouyoucos [6], the hydrometer method was adopted to estimate soil texture. Following the standard methodologies of Lindsay and Norwell [7], the available cationic micronutrients (Fe, Mn, Cu, and Zn) were extracted with DTPA (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M TEA, pH 7.3) maintaining the soil: extractant ratio of 1:2 and subsequently their contents were estimated using Atomic Absorption Spectrophotometer (AAS) [8]. In the analyzed soils from the research regions, a basic Pearson correlation coefficient analysis was done between the micronutrients and physicochemical characteristics.

3. RESULTS AND DISCUSSION

3.1 Physicochemical Properties of Soil

The examined soil characteristics' range and mean content of the studied blocks of Bankura district of West Bengal are shown in Table 1**.** Results regarding the particle size distribution of these soils have a sandy clay loam to sandy loam texture, with few samples having loamy sand texture.

The overall soil pH values of analyzed soils ranged from 4.83 to 7.39 and their average of 5.75, demonstrating the extreme acidity to neutrality of the soils. The lowest soil pH (4.83) was reported in Sarenga block soil, whereas its highest value was observed in the Bisnupur Block. This could be because of variation of the parent material from which these soils have been derived, soil texture and leaching of the basic cations. Chakravarti et al. [9] also conveyed similar results.

Normal electrical conductivity was discovered, and the soils in the research area did not exhibit any notable soluble salt buildup.

The OC content in 9 different Blocks of the Bankura District ranged from 0.09 to 1.08 % with a mean of 0.49%. The highest value of organic carbon (1.08%) was recorded in the Sarenga Block and the lowest (0.09%) in Chatna Block of Bankura district. It was observed that 49.49% of analyzed soils were low, 36.36% were medium and the remaining 14.14% were high in OC content (Table 2). The majority of soils' low to medium levels of OC may be caused by less application of organic manure along with poor ago-management practices such as mono-cropping and conventional tilling. Another reason might be attributed to the prevalence of high temperatures, which burn the soil's organic matter quickly, leaving these soils with low to medium levels of organic carbon. Similar status of OC was also reported by Deshmukh [10], Pandit et al. [11], and Das et al. [12].

3.2 Status of DTPA-extractable Cationic Micronutrients

The DTPA-extractable Zn content of analyzed soils (0 to 15 cm depth) of Bankura varied between 0.45 to 3.47 mg kg^{-1} with a mean content of 1.40 mg kg^{-1}. Among the different Blocks, the highest (3.47 mg kg^{-1}) available Zn content was recorded in Onda Block and the lowest (0.45 mg kg^{-1}) was observed in Bankura II Block. Out of 99 soil samples, 7 % were deficient, 36 % were medium, rest 57 % showed high Zn content. The maximum Zn deficiency was detected in block Bankura II (19%) and Chatna (19%) followed by Raipur (9%). The higher level of OC may be the cause of the high available zinc status. An additional explanation could be linked to the prevalence of high temperature which can increase the solubility and mobility of Zn in soil by increasing desorption of Zn from the adsorption sites. On the other hand, Zn being a divalent cation, its solubility and mobility are reduced 100 times with an increase in one unit of pH. Singh et al. [13], Sharma and Lal [14], Krishnamurthy and Srinivasamurthy [15] also noted a similar tendency.

With an average content of 2.31 mg kg^{-1}, the extractable Cu levels in the experimental soils of 9 distinct blocks in the Bankura showed a variation of 0.51 mg kg^{-1} to 5.29 mg kg^{-1}. The maximum Cu (5.29 mg kg^{-1}) was noted in Gangajalghati Block and the lowest (0.51 mg kg^{-1}) was obtained in Bisnupur Block. All the soil samples were sufficient in DTPA-extractable Cu content. Its high status is possibly because of the buildup of OC which has its affinity to influence the solubility and availability of Fe by chelation effect. There may be another explanation because of higher biological activity on the surface horizon. Similar findings had been documented by Reddy and Naidu [16] at Chennur Mandal of Kadapa District in Andhra Pradesh.

The DTPA-extractable Fe content falls under the high category. With a mean value of 30.46 mg kg^{-1}, the Fe content of experimental soils ranged from 6.52 to 56.27 mg kg^{-1}. The extractable Fe content was high which was above the critical limit (4.5 mg kg^{-1}) as proposed by Lindsay and

Table 1. Physicochemical characteristics in the soils of Bankura district

Block		pH	EC (dSm^{-1})	Organic C (%)	DTPA-Fe ($mg\ kg^{-1}$)	DTPA-Mn ($mg\ kg^{-1}$)	DTPA-Cu ($mg\ kg^{-1}$)	DTPA-Zn ($mg\ kg^{-1}$)	Textural Class
Bankura I	Range	5.83-6.27	0.04-0.11	0.1-0.81	12.31-33.8	4.73-21.35	1.16-4.35	0.54-1.44	SL to LS
	Mean	6.06	0.07	0.38	22.85	11.98	2.26	1.05	
Bankura II	Range	5.53-6.06	0.04-0.08	0.23-0.78	11.2-34.43	8.46-21.64	1.16-4.53	0.45-2.63	SCL to SL
	Mean	5.72	0.06	0.48	27.15	16.86	2.55	1.67	
Onda	Range	5.2-6.34	0.03-0.11	0.15-0.69	26.94-42.44	5.46-26.81	0.65-3.61	0.81-3.47	SCL to SL
	Mean	5.55	0.06	0.44	34.43	15.71	2.34	1.81	
Bisnupur	Range	5.81-7.39	0.04-0.12	0.32-0.92	6.52-46.66	4.9-16.29	0.51-3.59	1.04-2.46	SCL
	Mean	6.27	0.08	0.62	28.78	12.69	2.28	1.56	
Raipur	Range	5.18-5.83	0.05-0.28	0.12-0.95	21.03-39.65	8.29-21.45	1.38-3.5	0.5-1.8	SCL to LS
	Mean	5.52	0.11	0.55	31.86	14.58	2.31	1.25	
Sarenga	Range	4.83-6.1	0.04-0.3	0.16-1.08	35.99-56.27	10.33-26.26	1.04-4.08	1.04-1.81	SL to LS
	Mean	5.59	0.11	0.56	41.12	17.05	2.09	1.44	
Gangajalghati	Range	5.67-6.21	0.04-0.14	0.23-0.97	17.98-42.22	11.93-22	1.66-5.29	0.78-2.24	SCL to SL
	Mean	5.91	0.08	0.56	33.67	16.38	2.88	1.26	
Barjora	Range	5.03-5.55	0.03-0.12	0.18-0.61	16.7-42.6	10.46-20.52	1.61-3.64	0.83-2.33	SCL to SL
	Mean	5.34	0.07	0.37	32.82	15.38	2.23	1.48	
Chatna	Range	5.48-6.51	0.03-0.17	0.09-0.69	12.26-32.11	9.41-21.58	1.07-4.47	0.55-2.27	SCL to SL
	Mean	5.80	0.07	0.45	21.51	15.57	1.92	1.14	

Table 2. Rating limits for soil test values used in India

Nutrient	Rating of the soil test values		
	Low	**Medium**	**High**
Organic carbon (%)	<0.5	0.5-0.75	>0.75
Zinc (mg/ kg).	<0.6	0.6-1.2	>1.2
Copper (mg/ kg)	<0.2	0.2-0.4	>0.4
Iron (mg/ kg)	<4.5	4.5-9	>9
Manganese (mg /kg)	<3.5	3.5-7	>7

Table 3. Correlation-coefficient between DTPA-extractable micronutrients and physicochemical properties of soils of Bankura district

	pH	EC	OC	Fe	Mn	Cu	Zn
pH	1.00						
EC	-0.13	1.00					
OC	0.13	-0.04	1.00				
Fe	-0.14	0.08	0.34*	1.00			
Mn	-0.23*	-0.06	0.01	0.29**	1.00		
Cu	0.07	-0.12	-0.10	0.18	0.07	1.00	
Zn	-0.33**	-0.03	0.13	0.06	0.05	0.07	1.00

** Significant at 5 % level of significance ** Significant at 1% level of significance*

Norvell [7]. The soils of Chatna Block had the lowest mean value of Fe concentration (21.51 mg kg^{-1}), whereas the soils of Sarenga Block had the greatest mean value of Fe content (41.12 mg kg^{-1}). High available Fe status is perhaps because of the accumulation of OC which has its affinity to influence the solubility and availability of Fe through the chelation effect as reported by Sunandana et al. [17]. According to Hrangbung et al. [18], another explanation could be the washing out of basic cations from the surface soils.

Data shown in Table 1 specified that DTPA-extractable Mn content was varied from 4.73 to 26.81 mg kg^{-1} with its mean content of 15.13 mg kg^{-1}. Almost all the experimental soil was discovered to have Mn content well above the critical limit (3.5 mg kg^{-1}). Among the different Blocks, the lowest (4.73 mg kg^{-1}) available Mn was observed in Bankura I Block and its highest (26.81 mg kg^{-1}) values was noted in Onda Block. The enhanced Mn content in these soils could be due to increased acidity and binding of organic compounds produced during the breakdown of organic materials. The presence of Mn-bearing parent materials might also be responsible for this. Comparable outcomes were also documented by Singh et al. [13], Mandavgade et al. [19] and Sunandana et al. [17]. According to Jain et al. [20], the concentration of DTPA extractable micronutrients (iron, manganese, copper, and zinc) was highest in forest soil and at a depth of 0–15 cm and dropped as soil depth increased.

3.3 Correlation Between DTPA-extractable Cationic Micronutrients and Soil Physicochemical Properties

A simple Pearson correlation between DTPA-extractable cationic micronutrients and analysed soil characteristics was computed and is displayed in Table 3. Based on the findings of this examination, a substantial positive association between DTPA-extractable Fe and OC (r = 0.34*) was noted. One possibility for the positive link between Fe and soil OC is the development of Fe-organic chelates, which are comparatively more soluble. Additionally, this outcome was validated by the findings of Talukdar et al. [21], Ray et al. [22] and Nisab et al. [23]. The study's available Fe content had a non-significant negative correlation (r=-0.141) with pH. Iron hydroxide, which is not easily obtainable by plants, precipitates at higher pH values, as indicated by a negative association with pH.

It was discovered that the available Mn level in soil had a negative and substantial relationship with soil pH (r = -0.23*). The production of insoluble Mn-oxides at higher pH values may be the cause of the negative association between accessible manganese and soil pH. The outcomes of Patel et al. [24], Sunandana et al. [17], and Manasa et al. [25] are in good accord with these findings. There was a strong and positive connection between the DTPA-extractable manganese and iron (0.29**). These outcomes concur with Prasanna's [26] findings.

The co-relationship between soil pH and DTPA-extractable Zn was negative and significant (-0.33**). The precipitation that produces immobile forms of Zn as hydroxides and carbonates could be the reason for the negative association between Zn and pH. Additionally, this outcome was validated by the results of Mandavgade et al. [19]. The non-significant positive correlation found between OC and available Zn suggests that, as soluble Zn chelates are formed with soil organic matter, an increase in OC would likewise increase the amount of soil Zn.

The value of DTPA-extractable available Cu showed a non-significant negative correlation with OC (r = -0.01), which suggests that complex formation with organic matter lowers the availability of Cu when there is a high quantity of organic matter.

4. CONCLUSION

The soil reaction of nine blocks in the Bankura district of West Bengal - Bankura I, Bankura II, Onda, Bisnupur, Raipur, Sarenga, Gangajalghati, Barjora, and Chatna - is found to be highly acidic to neutral, with EC values less than 1 dSm^{-1} and the OC classified as low to medium. The 7% of soil samples were deficient, 36% were medium and the remaining 57% were high in DTPA-extractable Zn status whereas the DTPA-extractable Fe, Mn, and Cu content was high. The soil pH showed a significant negative correlation with available Zn, and Mn but a non-significant relationship with available Cu and Fe content. The OC content showed a significant positive correlation with Fe but a nonsignificant correlation with available Zn and Mn. Considering the DTPA-extractable cationic micronutrients content of the soils in West Bengal's Bankura district balanced fertilization with special emphasis on cationic micronutrients should be advocated for various crops to maintain soil fertility and increase crop productivity.

ACKNOWLEDGEMENT

The study is a part of the M.Sc. (Ag.) thesis of the first author. The authors would like to express their sincere gratitude to the Head of the Dept. of Soil Science and Agricultural Chemistry, Palli Siksha Bhavana, Visva-Bharati for the support given for smoothly experimenting.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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