DTPA-Extractable Zinc in Rice Soils and Its Availability to Rice

DHANESHWAR PADHAN*, ARUP SEN and BIPLAB PAL

Department of Agricultural Chemistry and Soil Science, Bidhan Chandra Krishi Viswavidyalaya, 741252 West Bengal, India.

http://dx.doi.org/10.12944/CWE.11.2.39

(Received: April 17, 2016; Accepted: June 18, 2016)

ABSTRACT

Zinc (Zn) deficiency is a fairly wide spread agronomic constraint in many of the world rice production regions. Information on soil Zn distribution is essential for understanding its chemical reactions and bioavailability. In this backdrop, we tried to find out the relationship between physic-chemical properties and DTPA-extractable Zn (available Zn) content of rice soils. For this eighty four (84) surface soil samples (0-20cm) were collected from three villages (viz. Saharapali, Nuagarh and Adgaon) of Bargarh district under the Hirakud Command Area of Odisha. Analytical observations revealed that the soils were slightly acidic in reaction with moderately high content of soil organic carbon. Considering the critical limit of available Zn in soils to be 0.6 mg kg^{-1}, all soils of the study area were found to be well supplied with DTPA-extractable Zn. Soil organic carbon (SOC) content maintained positive and significant correlation with available zinc content in soils. However, soil pH showed significant but negative correlation with available zinc content of soils.

Keywords: Available Zn, bioavailability, critical limit, DTPA-extractable Zn, soil organic carbon.

INTRODUCTION

Zinc is an important trace element which is essential for the healthy crop growth and metabolism[1]. Zinc is also vital for terrestrial life since it is required either as a structural component or reaction site in numerous proteins. It is required by rice in small quantity, but its deficiency has an adverse effect on healthy crop growth and yield may reduce up to 30 percent[2]. Zinc deficiency in soils and plants is of major concern since thirty per cent of world soils are Zn deficient[3]. In India 48.1 % of the soils are found to be Zn deficient[4] though the figure for the soils of Odisha were reported to be low[5]. Zinc deficiency is one of the most widespread nutrient disorders in lowland rice after nitrogen and phosphorus. Such deficiency arises from adoption of modern technology with intensive cultivation and growing of high yielding varieties and also shifting towards the use of high analysis NPK fertilizers with inadequate use of organics or no application of Zn fertilizers. Though it is required by plants in very trace amounts, its availability in soils for plants is a complex mechanism. Availability of Zn in soils for plants is a function of soil properties. Soil properties such as soil pH, redox potential, organic matter and moisture content exert large impact on adsorption-desorption and dissolution-precipitation reactions. Thus, soil properties regulate the amount of Zn dissolved in soil solution[6]. Soil pH is the master variable affecting nutrient availability and the nutrient zinc is not far behind in this process[7]. Increasing soil pH, especially above 6.5, results in decreased extractability and plant availability of soil Zn. Soil Zn is usually more available in soils with greater organic matter content[8] and a relatively higher proportion of clay[9, 6]. Exchange positions are important in maintaining the Zn level sufficient for wet land rice[10] and in this regard the cation exchange capacity of oils seems to play dominant role. The rise in soil pH increases the adsorption of Zn onto soil constituents such as metal oxides and clay minerals which is linked to significant decline in Zn concentrations in soil solution and plant tissues[11, 12]. Hirakud command area under the central western table land agro-climatic zones is the major paddy growing region of Odisha, popularly known as rice bowl of Odisha. The soils of this area are continuously under submerged condition which enables rice plants to absorb Zn mostly from solubilisation of bound Zn in the rhizosphere because the availability in the soils is very limited due to flooded condition[13].

Available Zn content in the paddy growing soils of Bargarh district of Odisha was reported to be high[5] though discrete patches of Zn deficient areas were identified in soils under the Hirakud command area. Distribution of available Zn content in the paddy growing soils of the study area has not been studied extensively so far. Knowledge on distribution of available zinc content in wetland rice soils and various soil properties influencing its availability might prove to be the best approach for obtaining reliable information about the status of zinc.Therefore, we took an attempt to study the DTPA- extractable Zn (available Zn) content and also its relationship with physic-chemical properties of soils in some villages of Bargarh Block under the Hirakud command area.

MATERIAL AND METHODS

Site Description

The study area comprising of Saharapali, Nuagarh and Adgaon villages in Bargarh district, Odisha, lies within the lower Hirakud Command area which falls under the Western Central table land Agro-climatic zones of Odisha. It has an elevation of about 189.3m above the msl. Most of the soils developed on Archean rocks. The soil types in these areas are mixed red and black type. Climate of these areas is characterized by dry hot summer, monsoon rains and cold winter receiving an average annual rainfall of 1527mm and experiencing mean annual temperature of 30-35^{0}C.

Soil sample collection and analysis

Surface soil samples (0-20cm) were collected during kharif (2015**)** before puddling of fields. Eighty four (84) composite soil samples were taken randomly from rice fields of the study areas. Moist soil samples were collected in the moisture box with the help of core sampler to estimate the bulk density following the standard protocol. The soil samples were further air dried, grinded and passed through the 2mm sieve for analysis of other soil chemical parameters. Oxidisable organic carbon of the soils was analyzed by the method of Walkley and Black[14]. Soil pH was measured in soil: water:: 1:2.5 suspension[15]. Electrical conductivity of the soils was determined by following standard protocol[15]. Cation exchange capacity of soils was estimated by following standard method[15]. Available zinc content of soils was measured in atomic absorption spectrophotometer (AAS) after extracting the soils with 0.005M DTPA (Diethylene triaminepenta acetic acid) in 1:2 ratio (Soil: Extractant) following the standard procedure[16].

Statistical Analysis

The data were subjected to multiple correlation study with the help of SPSS software version 20.0 for establishing the relationship between available Zn content in soils and physic-chemical properties of soils.

RESULT AND DISCUSSION

Physic-chemical properties of soils

The results of soil analysis pertaining some salient properties under study are presented in table.1, 2& 3. The mean values of the studied soil parameters indicated that the soils were slightly acidic in reaction with slightly high in SOC content and there was no accumulation of appreciable quantities of salt in all the study sites indicating that the soils were non-saline in nature. The pH of the soils ranged from 4.89 to 6.52 with average value 5.96, 5.19 to 6.75 with average value 6.09 and 4.99 to 6.86 with average value 5.88 in Saharapali, Nuagarh and Adgaon village respectively. Although the soil pH was slightly acidic in reaction it was well suited for growing rice in these areas. Electrical conductivity of the soils ranged from 0.12-1.20 (mean 0.34), 0.12- 1.90 (0.78) and 0.19-1.90 (0.80) in Saharapali, Nuagarh and Adgaon respectively. Such magnitude of salt content was reported in paddy growing soils of Karnataka[17]. Soil organic carbon (SOC) is an important attributes influencing the soil physical, chemical and biological properties. Highest amount of SOC content (gkg^{-1}) was observed in soils of Saharapali village (average 6.10) followed by Adgaon (5.68) and Nuagarh (5.67) village. The higher content of SOC could be due to in situ incorporation of rice stubbles and addition of organic manures[17]. Bulk density in soils of Saharapali, Nuagarh and Adgaon were found to be 1.26-1.65 (mean 1.42), 1.26-1.75 (1.49) and 1.34-1.68 (1.53) respectively. Occurrence of such high bulk density in these soils could be due to the intensive cultivation despite of having significant amount of organic matter. Puddling of soils intensively for growing rice under submerged condition leads to formation of dense soil layer with high bulk density. The mean cation exchange capacity (CEC) of soils of Nuagarh (14.95) was found to be higher compare to Adgaon (14.42) and Saharapali (12.38). Such occurrence of CEC in these soils could be due to the presence of various functional groups in the decomposed organic matter and also due to the finer fractions of

Table 1: Physic-chemical properties and available Zn content of paddy soils of Saharapali Village under lower region of Hirakud Command Area

Sl No.	pH	E.C (ds m^{-1})	B.D (Mg m^{-3})	SOC (gkg^{-1})	CEC [Cmol (p^{+})kg^{-1}]	Available Zn (ppm)
1	5.56	0.21	1.35	6.5	10.5	1.2
2	5.86	0.32	1.26	6.2	11.2	1.1
3	6.31	0.34	1.56	5.8	11.5	0.92
4	6.22	0.32	1.49	5.9	8.5	0.94
5	6.16	1.2	1.36	6	14.8	0.96
6	5.98	0.39	1.35	6.3	10.2	1.1
7	5.78	0.29	1.45	6.7	11.5	1.3
8	5.68	0.12	1.44	6.2	12.4	1.25
9	5.75	0.75	1.36	6	12.6	1.1
10	6.12	0.63	1.26	5.8	9.8	0.98
11	6.52	0.21	1.39	5.1	12.4	0.82
12	6.18	0.42	1.34	5.4	11.5	0.91
13	6.45	0.36	1.36	5.2	11.5	0.85
14	6.35	0.35	1.35	5.1	12.7	0.89
15	6.34	0.19	1.56	5.1	10.2	0.87
16	5.98	0.19	1.52	6.4	11.6	1.1
17	5.88	0.16	1.35	6.5	10.4	1.2
18	5.82	0.26	1.53	6.2	10.5	1.2
19	6.45	0.34	1.43	5.9	13.2	0.86
20	6.25	0.12	1.46	5.9	12.9	0.92
21	6.08	0.21	1.56	6	12.4	0.94
22	5.23	0.24	1.65	7.2	10.8	1.5
23	5.8	0.36	1.32	6.5	13.2	1.1
24	6.02	0.42	1.45	6.1	15.2	0.95
25	4.89	0.22	1.29	7.5	12.4	1.62
26	6.12	0.34	1.45	6.2	18.6	0.92
27	5.88	0.25	1.44	6.8	14.2	1.3
28	5.13	0.31	1.36	6.7	18.5	1.3
Range	4.89- 6.52	0.12- 1.20	1.26- 1.65	5.1- 7.5	8.5- 18.6	0.82- 1.62
Mean	5.96	0.34	1.42	6.10	12.38	1.08
SD	0.40	0.22	0.10	0.60	2.32	0.20

soils. Similar magnitude of CEC was reported in rice growing soils under the western central table land agro-climatic zones of Odisha[18].

DTPA-extractable Zn content in soils:

Availability of zinc in submerged rice soil is a complex phenomenon. As soil submergence due to rice cultivation is likely to influence the solubility of native Zn in soils either favorably or adversely it controls the Zn nutrition of rice. The total concentration of zinc in soils depends on the type of parent material and soil mineralogy, especially the concentration of quartz, which tends to dilute the concentration of most elements. Only a small fraction of total zinc is exchangeable or soluble[19]. The soils were well supplied with DTPA-extractable Zn (available Zn). Considering 0.6 mg kg^{-1} as the critical limit of available zinc (DTPA-extractable) in soils, all the soils under the three villages (Saharapali, Nuagarh and Adgaon) were found to be sufficient. Similar findings reported by some workers[5]. The available Zn content ranged from 0.82 mg kg^{-1} to

Table 2: Physic-chemical properties and available Zn content of paddy soils of Nuagarh Village under lower region of Hirakud Command Area

Sl No.	pH	E.C (ds m^{-1})	B.D (Mg m^{-3})	SOC (gkg^{-1})	CEC [Cmol(p+) kg^{-1}]	Available Zn (ppm)
1	5.36	0.56	1.52	6.2	15.2	1.1
2	5.98	0.36	1.58	5.9	16.4	0.98
3	5.45	0.24	1.42	6.9	14.3	1.23
4	5.5	0.89	1.46	6.5	9.8	1.2
5	6.45	1.5	1.36	5.2	12.5	0.87
6	6.23	1.4	1.48	5.4	13.2	0.91
7	6.52	0.23	1.49	5.1	16.3	0.82
8	6.16	0.35	1.47	5.6	12.5	0.93
9	6.32	0.68	1.39	5.3	15.8	0.88
10	6.75	0.96	1.26	4.5	18.2	0.72
11	6.45	0.12	1.37	5	14.5	0.87
12	5.56	0.32	1.39	6.8	16.5	1.1
13	6.36	1.3	1.63	5.2	17.5	0.89
14	6.21	0.19	1.56	5.7	17.2	0.9
15	6.52	1.7	1.63	5.1	18.5	0.81
16	5.86	0.21	1.45	5.8	18.6	0.95
17	5.92	0.56	1.36	6.2	20.1	0.92
18	5.76	0.68	1.45	6.9	14.8	1.2
19	5.65	0.96	1.68	6.7	10.2	1.1
20	5.19	0.42	1.64	7	11.5	1.42
21	6.29	1.9	1.36	5.5	12.4	0.88
22	6.2	0.32	1.35	5.3	12.6	0.85
23	6.42	0.41	1.75	4.8	9.8	0.78
24	6.32	0.38	1.65	5.2	12.4	0.86
25	6.23	1.6	1.56	5.3	17.2	0.89
26	6.45	1.9	1.47	5	14.6	0.81
27	6.56	0.63	1.45	5	16.1	0.8
28	5.98	0.96	1.65	5.6	19.8	0.97
Range	5.19- 6.75	0.12- 1.90	1.26- 1.75	4.5- 7.0	9.8- 20.1	0.72- 1.42
Mean	6.09	0.78	1.49	5.67	14.95	0.95
SD	0.41	0.56	0.12	0.71	2.94	0.16

1.62 mg kg^{-1} with average 1.08 mg kg^{-1} in Saharapali village, 0.72 mg kg^{-1}to 1.42 mg kg^{-1} with an average of 0.95 mg kg^{-1} in Nuagarh village and 0.70 mg kg^{-1} to 1.52 mg kg^{-1} with an average of 1.04 mg kg^{-1} in Adgaon village. Among the three villages, the highest amount of available Zn was reported from Saharapali village. Similar magnitude of available Zn (DTPA-extractable) content was reported from a rice based long-term experiment under the central western table land agro-climatic zones of Odisha[20]. Such a high content of available zinc might be due to higher amount of SOC as indicated by their strong relationship (r= 0.857**) and also due to the finer fractions of soils leading to increase surface area for ion exchange and hence contributed to higher amount of DTPA- extractable zinc in soils[21].

Relationship between DTPA-extractable Zn content and other physic-chemical properties of soils

Knowledge regarding the status of available Zn and its relationship with soil properties

Table 3: Physic-chemical properties and available Zn content of paddy soils of Adgaon Village under lower region of Hirakud Command Area

Sl No.	pH	E.C (ds m^{-1})	B.D (Mg m^{-3})	SOC (gkg^{-1})	CEC [Cmol (p+) kg^{-1}]	Available Zn (ppm)
1	5.87	0.64	1.54	5.8	20.2	0.99
2	5.25	0.78	1.39	6.8	18.6	1.23
3	5.69	0.84	1.65	6.5	17.2	1.1
4	5.86	1.6	1.45	5.9	14.3	0.98
5	5.35	0.56	1.36	6.7	15.7	1.2
6	5.64	1.4	1.48	6.5	14.2	1
7	6.14	1.9	1.54	4.3	12.4	0.82
8	6.35	0.69	1.59	4.4	14.5	0.78
9	6.86	0.65	1.45	3.8	15.2	0.75
10	6.19	0.34	1.52	4.9	14.6	0.8
11	6.75	0.32	1.65	4.2	12.9	0.7
12	6.24	0.89	1.56	4.1	13.2	0.79
13	6.25	1.9	1.39	5.6	16.3	0.86
14	6.1	0.19	1.36	5.9	15.2	0.87
15	5.64	0.87	1.5	5.8	10.4	1.2
16	4.99	0.23	1.65	6.9	9.7	1.52
17	5.46	0.35	1.63	6.2	11.2	1.3
18	5.88	0.63	1.61	5.6	10.5	1.1
19	5.78	0.78	1.65	6.4	14.3	1.2
20	5.98	1.3	1.64	5.7	13.6	0.98
21	5.92	1.6	1.35	5.2	18.6	0.97
22	5.64	1.4	1.65	6.9	16.9	1.2
23	592	0.54	1.34	5.2	13.4	0.97
24	5.93	0.52	1.35	5.4	14.2	0.99
25	5.39	0.25	1.65	6.8	15.6	1.32
26	5.62	0.32	1.68	6.5	16.5	1.21
27	5.45	0.23	1.64	5.9	13.8	1.35
28	6.39	0.78	1.65	5.2	10.5	0.89
Range	4.99- 6.86	0.19- 1.90	1.34- 1.68	3.8- 6.9	9.7- 20.2	0.70- 1.52
Mean	5.88	0.80	1.53	5.68	14.42	1.04
SD	0.43	0.52	0.12	0.92	2.61	0.21

Table 4: Relationship between available Zn and soil properties

	pH	Electrical conductivity	BD	SOC	Cation Exchange Capacity	Available Zn
pH	1					
Electrical conductivity	.201	1				
BD	-.071	.052	1			
SOC	-.839**	-.273*	-.022	1		
Cation Exchange Capacity	.048	.246*	-.028	-.061	1	
Available Zn	-.916**	-.294**	.086	.857**	-.199	1

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

is helpful in understanding the inherent capacity of soils to supply Zn in optimum amount for plant nutrition. Due to continuous perturbation, soils under a particular cropping system may affect physic-chemical properties which may modify the DTPA-extractable Zn content and its availability to crops. From the correlation matrix, it was clear that available Zn maintained positive and significant correlation (P<0.01 level) with SOC (r= 0.857**), significant but negative correlation with soil pH (r= -0.916**) indicating the availability of Zn decreases with increase pH. Similar results reported by many workers[22, 23, 24].

EC- Electrical Conductivity, BD- Bulk Density, SOC- Soil Organic Carbon, CEC- Cation Exchange Capacity Organic matter is helpful in improving the soil structure and aeration, hence protecting the precipitation of Zn into unavailable forms. Therefore, availability of Zn improves significantly with increase in organic matter. The DTPA-extractable Zn was significantly and negatively correlated with pH and positively correlated with SOC[25]. An inverse relationship between soil pH and Zn availability was reported[26]. Soil organic carbon content showed significant but negative correlation with soil pH.

Crop management (like native Zn content of soil, soil pH, organic matter, submergence, partial pressure of CO_2, organic acids) and environmental factors combinely influence the availability of Zn to rice crops. However, SOC content and pH are the main soil characteristics which control the availability of Zn in soils. It is apparent from the study that the soils are adequately supplied with DTPA-extractable Zn. Higher amount of DTPA-extractable Zn were obtained in soils with high SOC content and low pH values. To increase the yield potential of paddy growing areas, farmers are advocated to use organic matter or crop residues along with application of chemical Zn fertilizers. Thus, maintaining the soil adequate in available Zn content for plant nutrition.

REFERENCES

1. Alloway, B.J., Zinc in soils and crop nutrition. International zinc association (IZA), 168 Avenue de Tervueren, 1150 Brussels-Belgium, www.zincworld.org. (2008)
2. Hafeez, B., Khanif, Y.M., Saleem, M., Mastoi, M.I., & Gandahi, A.W., Zinc status of soils of Malaysia in relation to some physic-chemical properties. *Pakistan Journal of Agriculture, Engineering and Veternary science, **31***(1): 33-41 (2015)
3. Alloway, B.J., Zinc in soils and crop nutrition. International zinc association (IZA), 168 Avenue de Tervueren, 1150 Brussels-Belgium, www.zincworld.org. (2004)
4. Kumar, M., & Babel, A.L., Available micronutrient status and their relationship with soil properties of Jhunjhunu Tehsil, District Jhunjhunu, Rajasthan, India. *Journal of Agricultural Sciences, **3***(2): 97 (2011)
5. Singh, M.V., Jana, D., & Maji, A. K., Zinc

fertility status in soils of Orissa. Micronutrients Fertility mapping for Indian soils. Tech. Bulletin AICRP, Micronutrients, IISS, Bhopal **7**, 1-60 (2008)

6. Alloway, B.J., Soil factors associated with zinc deficiency in crops and humans. *Environment Geochemical Health, **31***: 537-548 (2009)
7. Rengel, Z., Availability of Mn, Zn and Fe in the rhizosphere. *Journal of Soil Science and Plant Nutrition, **15***(2): 397-409 (2015)
8. Iratkar, A.G., Giri, J.D., Kadam, M.M., Giri, J.N., & Dabhade, M.B., Distribution of DTPA extractable micronutrients and their relationship with soil properties in soil of Parsori watershed of Nagpur district of Maharashtra. *Asian Journal of Soil Science, **9***: 297-299 (2014)
9. Rengel, Z.,. Agronomic approaches to increasing zinc concentration in staple food crops. In: I. Cakmak, R.M. Welch (ed.) Impacts of Agriculture on Human Health and Nutrition. UNESCO, EOLSS Publishers, Oxford, UK. (2002a)
10. Murthy, A. S P., Zn fractions in wetland rice soils and their availability to rice. *Soil Science*, **133**: 150-154 (1982)
11. Gao, X., Bioavailability of zinc to aerobic rice. Wageningen University & Research Centre. (2007)
12. Hawkesford, M. J., & Barraclough, P., Zinc in soils and crop nutrition. In: Sadeghzadeh B, Rengel Z, (eds). The molecular and physiological basis of nutrient use efficiency in crops, Wiley-Blackwell, Oxford, UK. (2011)
13. Achim, D., & Thomas, F., Rice: Nutrient disorder and nutrient management. In: Mineral Deficiencies [eds], Zinc. International Rice Research Institute. Philippines. (2000)
14. Walkley, A., & Black, C.A., Estimation of organic carbon by the chromic acid titration method. *Soil Science,* **47**:29-38 (1934)
15. Jackson, M. L., Soil Chemical Analysis. Prentice-Hall of India Private Ltd.,New Delhi. (1973)
16. Lindsay, W. L., & Norvell, W. A., Development of a DTPA test for zinc, iron, manganese and copper. *Soil Science Society of America Journal*, **42**: 421-428 (1978)
17. Selvaraj, S., Basavaraj, B., & Hebsur, N. S., Distribution of Different Forms of Zinc in Paddy Growing Soils in Selected Villages of Gangavati Taluk, North Karnataka. Research *Journal of Agricultural Sciences, **3***(6): 1170-1174 (2012)
18. Padhan, D., Rout, P. P., & Sahoo, T., Surface and Sub-surface distribution of available potassium in rice growing soils under western central table land Agro-climatic zones of Odisha. *Journal of Agroecology and Natural Resource Management **2***(5): 365-368 (2015)
19. Robson, A.D., Zinc in soils and plants. Proceedings of the International Symposium on Zinc in Soils and Plants. The University of Western Australia, sept.27-28 (1993)
20. Pradhan, A.K., Beura, K.S., Das, R.., Padhan, D., Hazra, G.C., Mandal, B., De, N., Mishra, V.N., Polara, K.B., & Sharma, S., Evaluation of extractability of different extractants for zinc and copper in soils under long-term fertilization. *Plant Soil and Environment, **61***(5):227–233 (2015)
21. Sharma, R. P., Singh, M., & Sharma, J. P., Correlation studies on micronutrients vis-a-vis soil properties in some soils of Nagaur district in semi-arid region of Rajasthan. *Journal of the Indian Society of Soil Science, **51***: 522-527 (2003)
22. Yadav, K. K., Micronutrient Status in Soils of Udaipur District of Rajasthan. *Hydrology Journal, 31*(3&4) (2008)
23. Talukdar, M.C., Basumatary, A., & Dutta, S.K., Status of DTPA–extractable Cationic Micronutrients in Soils under Rice and Sugarcane Ecosystems of Golaghat Dictrict in Assam. *Journal of the Indian Society of Soil Science, **57**(*3): 313-316 (2009)
24. Sidhu, G. S., & Sharma, B. D., Diethylene triamine penta-acetic Acid-Extractable Micronutrients Status in Soil under a Rice-Wheat System and Their Relationship with Soil Properties in Different Agro-climatic Zones of Indo-Gangetic Plains of India. *Communications in Soil Science and Plant Analysis, **41***(1): 29 – 51 (2010)
25. Mathur, G. M., Deo, R., & Yadav, B. S., Status of zinc in irrigated north-west plain soils of

Rajasthan. *Journal of the Indian Society of Soil Science,* ***54***(3): 359-361 (2006)

26. Zeng, F., Ali, S., Zhang, H., Quyang, Y., & Qiu, B., Wu, F., & Zhang, G., The influence of pH and organic matter content in paddy soil on heavy metal availability and their uptake by rice plants. *Environment Pollution,* ***159***: 84-91 (2011)