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Critical Limit of Zinc for Rice in Calcareous Soils

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ABSTRACT

A pot culture experiment was conducted to determine the critical limit of Zn for rice grown in calcareous soils collected from the High Ganges River Floodplain (AEZ 11). The soils contained $CaCO_3$ 0.68-6.95%, pH 7.1-7.8, organic matter 1.32-2.49% and clay 9.0-33.0%. The available Zn content of soils was estimated by three extraction methods and the amount of extraction followed the order of 0.1M HCl > 0.005 M DTPA (pH 7.3) >1M NH_4OAc (pH 7.0). The critical levels of DTPA, HCl and NH_4OAc extractable Zn were found to be 0.83, 1.80 and 0.40 ppm, respectively for rice as determined by Cate and Nelson's graphical procedure. The DTPA extractable Zn showed a positive correlation with DM yield and plant Zn content. Thus, the DTPA extraction can be regarded as a good method for determining available Zn status in calcareous soils.

Key words: Calcareous soil, critical limit, rice, zinc.

INTRODUCTION

Zinc deficiency is common in maize and rice, and for all crops grown in calcareous soils. This element deficiency has arisen in Bangladesh mainly due to continuous mining of soil nutrients for increase cropping intensity (180% at present). The availability of Zn in the soil varies widely depending on the soil properties. The calcareous soils have low to medium extractable Zn content (Jahiruddin and Islam 1999). Critical limit (CL) of a nutrient in soils refers to a level below which the crops will readily respond to its application. This level varies with crops, soil, and the extractants used. Zinc application is usually made on the basis of soil fertility class, thus the crop response to added Zn is not always obtained. The information on Zn fertilizer use emanating from soil testing laboratories should be based on the critical limits of extractable Zn for different crops and soils. In this country, most of the cultivable land especially calcareous soils are showing Zn deficiency invariably and information in relation to zinc fertilizer management is inadequate. Therefore, the situation justifies a need to determine the critical limit of Zn for rice in calcareous soils in order to formulate the optimum fertilizer dose of Zn for rice for obtaining satisfactory yield.

MATERIALS AND METHODS

A Pot experiment with Boro rice (BRRI dhan 29) was conducted in the net house of the Department of Soil Science, Bangladesh Agricultural University (BAU), Mymensingh with 16 top soils (0-15 cm). The soils were collected from different locations of High Ganges River Floodplain (AEZ 11) in the Rajshahi district. The sampling sites had a wide range of land types (Table 1). There were two Zn

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treatments viz. 0 and 5 ppm (soil basis). Each of the treatments was replicated thrice in a Completely Randomized Design (CRD) to give a total of 6 (2 x 3) pots for each soil. Thus the total number of plastic pots used in this study was 96 (6 x 16). An amount of 2.5 kg of each soil was weighed into a series of 6 pots and three rice seedlings were planted in each pot A basal application was made with 100 ppm N, 25 ppm P, 40 ppm K and 25 ppm S in each pot to support normal plant growth. The nutrients (N, P, K, S and Zn) were added in solution at the rate of 10 ml/pot through $CO(NH_2)_2$, KH_2PO_4, KCl, $CaSO_4$. $2H_2O$ and $ZnCl_2$, respectively and mixed thoroughly with the soil. The soils of all pots were kept moist with addition of distilled water periodically. In all pots 50 mg N/kg soil as urea in solution was applied at vegetative stage after three weeks of planting. The plants were cut at the stage of 6 weeks, washed with distilled water and dried in an oven at 65^{o}c for 24 hours. The initial soil samples were analyzed for both mechanical and chemical compositions following standard methods (Page *et al*., 1989). Available Zn content of soil was determined by three extractants viz. DTPA (0.005 M), HCl (0.1 M) and NH_4OAc (1 M). The extractable Zn content of soil and Zn content of plant in the digest were determined directly by atomic absorption spectrophotometer.

Table 1. General characteristics and extractable Zn of the soils

Soil (location)	Soil series	Textural class (USDA)	pH	% organic matter	% $CaCO_3$	Extractable Zn (ppm)		
						DTPA-Zn	HCl-Zn	NH_4OAc-Zn
Domandi	Sara	Silt loam	7.6	1.81	0.68	0.72	4.11	0.28
Shibpur	Gopalpur	Silt loam	7.7	2.37	1.23	0.80	7.20	0.26
Bashpukuria-1	Gopalpur	Silt loam	7.6	2.01	0.84	1.24	1.20	0.61
Bashpukuria-2	Ishurdi	Silt loam	7.5	2.25	6.95	1.08	9.46	0.41
Bashpukuria-3	Mehandiganj	Silt clay loam	7.3	2.45	6.85	1.08	0.64	0.16
Kathalbaria-1	Gopalpur	Silt loam	7.7	2.33	5.75	0.62	0.81	0.22
Dhopapara	Sara	Silt loam	7.6	2.29	5.06	0.72	0.76	0.28
Chakpolashi-1	Sara	Silt loam	7.7	1.61	4.89	0.90	1.38	0.33
Chakpolashi-2	Ishurdi	Silt loam	7.6	2.49	1.56	0.88	6.65	0.31
Laudhara	Sara	Silt loam	7.8	1.24	1.81	0.90	1.48	0.34
Meramatpur	Gopalpur	Silt loam	7.6	2.41	2.21	1.18	8.56	0.56
Sreekhandi	Sara	Silt loam	7.8	1.32	4.29	0.86	4.00	0.27
Zhikra	Sara	Silt loam	7.7	1.53	2.50	1.16	7.99	0.67
Majhigram	Ghior	Silt loam	7.1	2.17	1.25	1.24	0.98	0.14
Baroipara	Ghior	Silt loam	7.5	2.33	1.23	1.42	4.28	0.42
Daulatpur	Ishurdi	Silt loam	7.7	1.49	0.88	0.78	1.90	0.22
Range		------	7.1-7.8	1.32-2.49	0.68-6.95	0.62-1.42	0.64-9.46	0.14 -0.67
Mean		------	7.6	2.01	2.00	0.97	3.84	0.34

The critical level of soil Zn was determined by following two approaches: graphical and statistical. The graphical method was followed as per Cate and Nelson (1965). In this procedure, a scatter diagram of the relative yields (Bray's per cent yield) as Y-axis versus soil test values as X-axis was plotted.

The statistical approach was used as developed by Waugh *et al*. (1973).

RESULTS AND DISCUSSION

Extractable Zn in soils by different methods

Results of extractable Zn by different methods are reported in Table 1. The amount of extractable Zn varied markedly depending on the soils and extractants used. The lowest amount of Zn was extracted by 1M NH_4OAc and the highest by 0.1M HCl. The amount of DTPA extractable Zn in different soils varied from 0.62 to 1.42 ppm (Table 1). The DTPA extractable Zn was negatively correlated with soil pH (r = - 0.511*) and was positively correlated with available P (r = 0.749**), exchangeable K (r = 0.545*) and exchangeable Mg (r = 0.514*) contents (Table 2). The negative relationship between soil Zn by different extractants and soil pH has been observed by many workers in the past (Agarwal and Sastry 1995; Jahiruddin *et al.* 1992). The available Zn extracted by 0.1M HCl in different soils ranged from 0.64 to 9.46 ppm ((Table 1). The HCl extractable Zn showed no significant relationship with any of the soil properties tested (Table 2). Such results otherwise indicate that the HCl extracted Zn also from non-exchangeable pool including $CaCO_3$ bound Zn. Hence due to acidic action, HCl extracted more Zn than the other extractants. The amount of Zn extracted by 1M NH_4OAc (pH 7.0) ranged from 0.14 to 0.67 ppm having a mean value of 0.34 ppm in different soils under study (Table 1). Higher value of Zn by all extractants were obtained with Baroipara, Bashpukuria (1, 2) and Zhikra soils showing a good relationship between any pair of extractants. Such result indicates that although the ability of Zn extraction for this pair of extractants was not same, the trends of Zn displacement from soils into solution by them were similar. The best correlation (r = 0.502*) was found between DTPA-Zn and NH_4OAc-Zn. The DTPA-Zn was weakly correlated with HCl-Zn (r = 0.218^{ns}) and similarly the HCl-Zn was weakly associated with NH_4OAc – Zn (r = 0.379^{ns}).

Table 2. Relationship (r value) of extractable Zn with selected soil properties

Extractable Zn	Clay	pH	OM	Avail. P	Ex. K	Ex. Ca	Ex. Mg
DTPA–Zn	0.466^{ns}	-0.511*	0.183^{ns}	0.749**	0.545*	-0.332^{ns}	0.512*
HCl–Zn	-0.185^{ns}	0.156^{ns}	0.188^{ns}	0.316^{ns}	0.021^{ns}	0.108^{ns}	-0.187^{ns}
NH_4OAc- Zn	-0.276^{ns}	0.30^{ns}	-0.110^{ns}	0.451^{ns}	-0.059^{ns}	-0.147^{ns}	-0.227^{ns}

** Significant at 1% level, * Significant at 5% level, ns = not significant

Dry matter yield

Dry matter weight of rice plants in Zn treated pots varied from 8.91 to 26.20 g/pot, against 6.91 to 25.90 g/pot in the Zn control pots (Table 3). Addition of Zn increased dry matter yield to a considerable extent in soils having low available Zn content (0.62 to 0.89 ppm DTPA-Zn). The Bray's percent yield ranged from 77.6 to 99.2 depending on the soils under study (Table 3).

Table 3. Effect of added Zn on the dry matter weight and Zn content of rice plants at 6 weeks of growth

	Dry matter weight (g/pot)			Zn content (ppm)	
Location	Zn^+	Zn^-	% Relative yield	Zn^+	Zn^-
Domandi	22.12	21.96	99.2	44.7	30.0
Shibpur	20.47	18.74	91.6	59.0	39.3
Bashpukuria-1	18.87	18.05	95.7	56.3	57.7
Bashpukuria-2	22.83	21.82	95.6	71.3	56.0
Bashpukuria-3	19.03	18.33	96.3	110.0	75.7
Kathalbaria-1	18.98	16.62	87.6	60.0	49.7
Dhopapara	20.48	19.06	93.1	47.3	37.3
Chakpolashi-1	19.69	19.07	96.9	64.3	55.3
Chakpolashi-2	26.20	25.90	98.8	83.3	63.0
Laudhara	18.37	16.71	91.0	66.0	53.7
Meramatpur	20.21	19.00	94.0	57.7	49.3
Sreekhandi	8.91	6.91	77.6	74.3	67.3
Zhikra	17.26	17.08	99.0	69.0	47.7
Majhigram	19.29	18.61	96.5	72.7	63.0
Baroipara	23.25	21.96	94.5	69.0	47.7
Daulatpur	16.40	16.16	98.6	105.0	42.5
Range	8.91-26.20	6.91-25.90	77.6-99.2	44.3-110.0	30.0-75.7
Mean	19.31	18.30	94.1	69.4	52.2

Results are the means of 3 replications, Zn^+ = Zn added, Zn^- = Zn not added

The Zn extraction by DTPA method showed significant and positive correlation with dry matter yield and Zn content (r = 0.551* and r = 0.573* respectively) (Table 4). The amount of Zn extraction by HCl and NH_4OAc did not exhibit significant relationship with DM yield or Zn uptake by plants.

Table 4. Relationship (r value) of extractable Zn with DM yield, Zn content and Zn uptake and relative DM yield of rice

Extractable Zn	DM yield	Zn content	Zn uptake	Relative DM yield
0.005M DTPA	0.551*	0.573*	0.369^{ns}	0.069^{ns}
0.1M HCl	0.264^{ns}	-0.159^{ns}	0.082^{ns}	-0.005^{ns}
1M NH_4OAc	0.099^{ns}	-0.142^{ns}	-0.014^{ns}	0.107^{ns}

* = Significant at 5% level, ns = Not significant

Critical level of soil available Zn

In the graphical procedure, the critical level of DTPA extractable Zn for rice was found to be 0.83 ppm and that for HCl and NH_4OAc extraction methods appeared to be 1.8 and 0.40 ppm, respectively (Figs. 1-3). Chhibba *et al.* (1997) reported that both graphical and statistical methods indicated 0.76 ppm as the critical value of Zn deficiency soils. The critical limits of Zn for DTPA, HCl and NH_4OAc extraction methods by using statistical approach are 0.83, 2.6 and 0.26 ppm respectively. The statistically calculated critical level (CL) of soil Zn (0.83 ppm) for rice determined by DTPA extraction method was same as that of graphical method while the CL values of HCl (1.8) and NH_4OAc (0.40 ppm) extractable Zn varied considerably between graphical and statistical methods.

The study thus indicates that DTPA is a better extractant for assessing available zinc status of calcareous soils. It is expected that the AEZ 11 soils will likely respond to Zn application when the soils contain less than 0.83ppm DTPA extractable Zn.

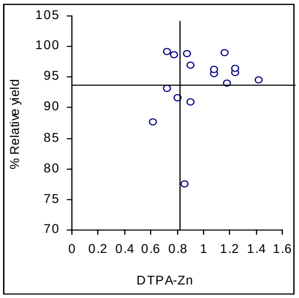

Fig. 1 Critical limit of DTPA extractable Zn for rice

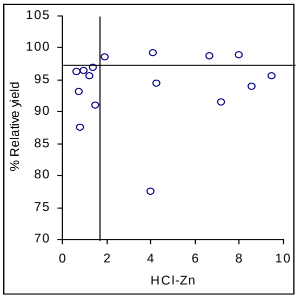

Fig. 2 Critical limit of HCl extractable Zn for rice

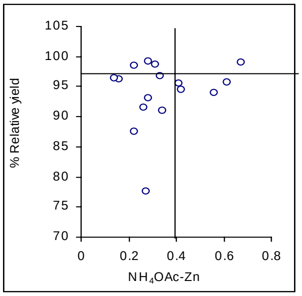

Fig. 3 Critical limit of NH_4OAc extractable Zn for rice

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