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Estimation of critical limit of zinc for rice (*Oryza sativa*) in alluvial soils of Agra district, Uttar Pradesh

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ABSTRACT

A greenhouse study was conducted with 20 representative soils from Agra district using rice (Avena sativa) as test at Raja Balwant Singh, College Bichpuri, Agra (Uttar Pradesh) to estimate the critical limit of zinc in soils and rice plants for predicting its response to zinc application using DTPA-$CaCl_2$, DTPA-NH_4HCO_3, 0.01M EDTA-$(NH_4)_2$ CO_3 0.01N HCl. Among these, four extract ants, 0.1NHCl extracted the highest amount of zinc from the soils. The extraction power of DTPA-$CaCl_2$ was found to be low. The extractability of zinc was in the order of 0.1N HCl > EDTA – $(NH_4)_2CO_3$ > DTPA-NH_4HCO_3 > DTPA-$CaCl_2$. DTPA $CaCl_2$, in general, provided the best estimate of available zinc as it showed the highest values of correlation coefficients with uptake of Zn and dry matter yield of rice crop. DTPA - NH_4HCO_3 and EDTA-$(NH_4)_2CO_3$ also showed promising results as these, methods were significantly correlated with yield and zinc uptake. Hydrochloric acid (0.1N) did not predict dry matter yield and Zn uptake significantly. The critical levels of soil available Zn with DTPA-$CaCl_2$, DTPA-NH_4HCO_3 and EDTA-$(NH_4)_2CO_3$ were 0.53, 0.52 and 1.0 mg kg-1, respectively for response of rice crop in alluvial soils to zinc. The critical level of zinc in rice plants below which response of crop to Zn application may be expected was 18.0 mg kg^{-1}.

Keywords: Critical limit, extract ants, dry matter yield, alluvial soil, rice

INTRODUCTION

Rice (*Oryza sativa L*) is one of most important food crop and a primary food source for more than one third of world's population. India has the largest area under rice cultivation accounting for 29.4% of the global rice area. But the productivity level in India is lower (2.04t ha^{-1}) as compared to other countries. Productivity of rice depends upon balanced application of nutrients. Zinc is one of the essential micronutrients and its importance for crop productivity is similar to that of major nutrients. Zinc plays an important role in different plant metabolism processes like development of cell wall, respiration, photosynthesis chlorophyll formation, enzyme activity and other biochemical functions. It has been proved that the application of Zn greatly influence growth, yield and quality of rice (Sirari *et al.* 2017). This emphasizes the need for careful appraisal of Zn status through soil and plant test for judicious use of Zn fertilizer. A variety of extract ants including acids, salts and chelates have been tried (Lindsay and Norvell, 1978, Singhal 2003) for estimating available Zn in soil. Since the suitability of a soil test is more likely to vary depending upon the soil properties and plant species, the evaluation of soil test methods for zinc with soils of wide variability in respect of their characteristics thus assume great importance. The information on a suitable soil test for zinc is not available in respect of alluvial soils of Agra. Further, realizing the importance of zinc in rice plant, an attempt is therefore, being made to evolve a suitable extract ant and the critical limit of Zn in soils and rice crop for making Zn fertilization more rational.

MATERIALS AND METHODS

Twenty representative soil samples were collected in bulk from plough larger (0-20 cm) from various locations in Agra district. The collected soil samples were separately air dried, ground and passed through 2 mm sieve. After thoroughly mixing the soil lot, 4kg of soil was filled in polyethylene lined earthen pots. From each soil lot, because of three replications, three pots were filled. The recommended doses of N, P and K for the paddy crop were incorporated into each soil in the form of solution prepared from 'Analar' grade urea, diammonium phosphate and potassium chloride. Rice was planted as the test crop during monsoon 2009. Five seedlings were planted in each pot. Equal amount of water was applied to the pots at the time of irrigation and for this purpose demineralized water was used. The crop (paddy) was allowed to grow up to 60 days. Then the above ground portion of crop was harvested. The harvested plants of the crop were washed with distilled water and rinsed twice with double distilled water before drying in an oven at 700c. After drying, the dry matter yields were recorded. Plant samples were digested in HNO_3 and $HClO_4$ mixture and in the digest, Zn was determined on a atomic absorption spectrophotometer.

The original soil samples used in pot culture experiment were analysed for their physico-chemical properties by adopting standard procedure (Jackson 1973). These soil samples were extracted for available Zn by different extra cants (Table 1). Zinc in these extract ants was determined on atomic absorption spectrophotometer. The critical limit of Zn in soil and rice plants was determined following. The graphical approach proposed by Cate and Nelson (1965).

RESULTS AND DISCUSSION

Soil characteristics:

The soils (twenty in number) were analysed for some physico-chemical characteristics (Table 1). These soils used under pot culture study were found moderately alkaline in reaction varying in soil-pH from 7.3 to 9.7. The total soluble salts were within the range of 0.06 to 0.40 dSm^{-1}. The soils in general, were low in organic carbon, which ranged from 3.5 to 6.8 g kg^{-1}. They contained varying quantities of $CaCO_3$, which varied from 5.0 to 25.0 g kg^{-1}.

Table 1: Physico-chemical, characteristics of the soils used in pot experiment using paddy as test crops

Location	pH	EC (dSm^{-1})	$CaCO_3$ (g kg^{-1})	Organic carbon (g kg^{-1})	Zinc
Achanara	8.5	0.40	5.0	3.9	0.50
Barara	8.3	0.36	10.0	4.4	0.50
Bichpuri	8.1	0.28	10.0	3.6	0.46
Gelana	8.5	0.12	5.0	4.7	0.63
Gamari	7.9	0.22	5.0	5.9	1.30
Khanda	7.6	0.18	5.0	5.5	1.20
Khandauli	8.0	0.42	10.0	3.5	0.76
Kakretha	8.3	0.44	10.0	4.6	0.30
Kenjara	7.7	0.34	15.0	4.0	0.41
Lalau	8.6	0.28	10.0	4.2	0.30
Nagla Basai	7.9	0.38	5.0	4.0	0.54
Mirajapur	7.9	0.24	10.0	4.9	0.58
Maghtai	7.8	0.20	10.0	4.1	0.48
Nanpur	7.7	0.26	10.0	3.9	0.61
Patholi	8.0	0.30	10.0	4.6	0.59
Raibha	7.6	0.20	5.0	5.0	0.68
Rasulpur	8.1	0.26	5.0	4.8	0.52
Sadarban	7.8	0.32	10.0	5.0	0.69
Sahara	7.9	0.36	10.0	4.0	0.63
Sewla	7.8	0.34	5.0	3.6	0.56

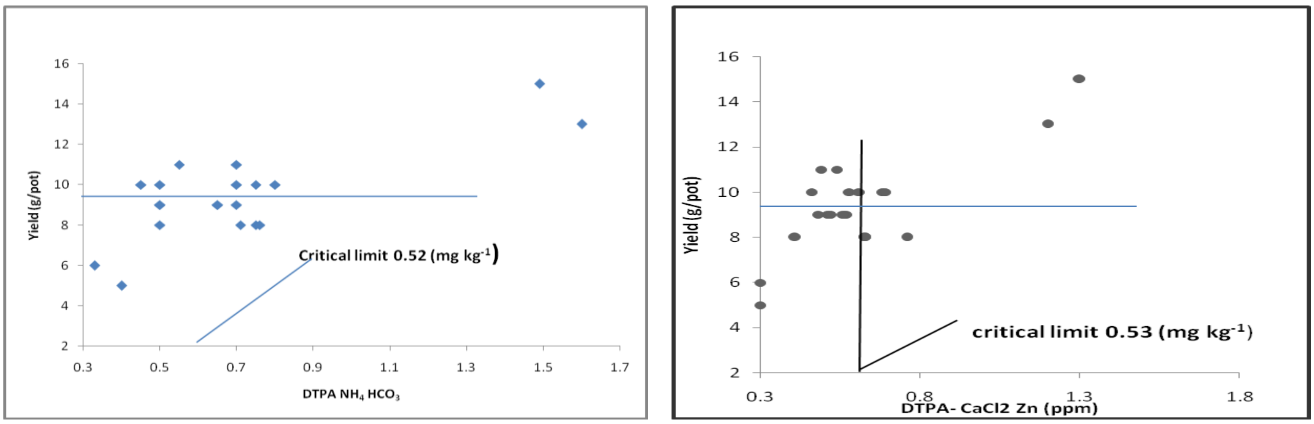


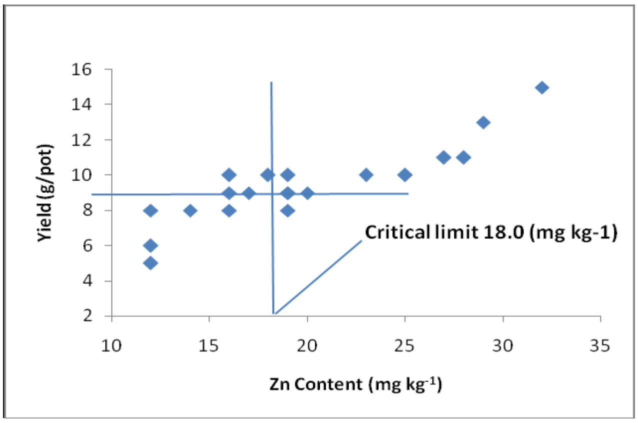
Fig.1: Scatter diagram showing relationship between soil test for Zn and yield of paddy

Available Zn in paddy soils

The values of available zinc in soils growing paddy determined by four chemical extractants are presented in Table 2

Table 2: Quantity of zinc extracted by different chemicals reagents from different soils

S.No.	Zinc (mg kg^{-1})			
	0.1N HCl	EDTA$(NH_4)_2$ CO_3	DTPA NH_4 HCO_3	DTPA $CaCl_2$
1.	3.20	1.10	0.65	0.51
2.	2.50	0.90	0.55	0.49
3.	1.60	0.82	0.75	0.63
4.	3.25	0.80	0.50	0.46
5.	2.10	2.40	1.49	1.30
6.	2.50	2.00	1.60	1.20
7.	1.60	1.10	0.76	0.76
8.	1.73	0.60	0.40	0.30
9.	3.40	0.80	0.50	0.41
10.	2.50	0.55	0.33	0.30
11.	2.10	1.40	0.70	0.54
12.	0.86	1.05	0.70	0.58
13.	3.80	1.00	0.50	0.48
14.	1.75	1.85	0.75	0.61
15.	1.56	0.90	0.70	0.57
16.	1.85	1.05	0.80	0.68
17.	2.40	0.75	0.65	0.52
18.	2.90	0.95	0.45	0.69
19.	0.74	0.60	0.71	0.63
20.	2.30	0.65	0.50	0.56



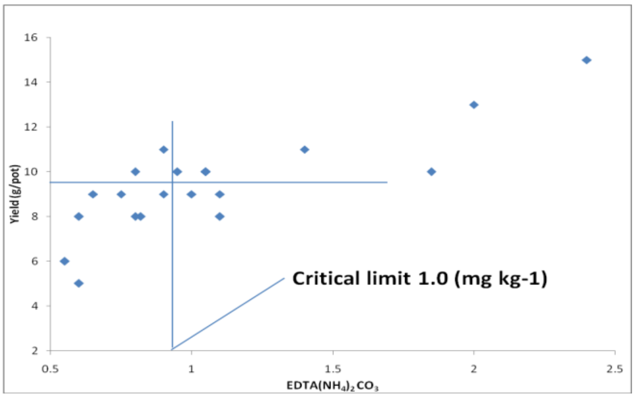


Fig. 2: Scatter diagram showing relationship between Zn content in plant and yield of paddy

The available Zn extracted by different extractants varied from 0.30 to 3.80 mg kg^{-1} soil. The maximum amount of zinc was extracted with 0.1N HCl and minimum in case of DTPA-$CaCl_2$. The extractability of zinc was in the order of 0.1N HCl > EDTA-$(NH_4)_2CO_3$ > DTPA-NH_4HCO_3 >DTPA-$CaCl_2$. It is quite evident that the capacities of extractants depend on nature of the complexing agent, pH, and presence of other chemical compounds in the extractant, soil characteristics and time of contact. Naik and Das (2010) recorded appreciable higher concentration of zinc with 0.1N HCl than with other reagents.

Yield and uptake of zinc by paddy crop

An ideal soil test method must give an idea about crop response to the application of the nutrient under test. The yield is generally taken as index of crop response to the application of zinc. In addition, its relationship with zinc by plants has also been considered with a view to have better predictability for the soil test method (Table 3). A study of Table 4.10 brings out that the yield of paddy ranged from

5.0 to 15.0 g/pot. The concentrations of Zn ranged from 12.0 to 32.0 mg kg^{-1}, respectively. The corresponding ranges for the values of Zn uptake by paddy plants were from 60.0 to 480.0 µg /pot (Table 3).

Table 3: Yield, content and uptake of Zn by paddy crop (average of three replications)

S.No	Yield (g/pot)	Zn Content (mg kg^{-1})	Zn uptake (µg/pot)
1.	9.0	19	171.0
2.	11.0	27	297.0
3.	8.0	14	112.0
4.	10.0	23	230.0
5.	15.0	32	480.0
6.	13.0	29	377.0
7.	8.0	16	128.0
8.	5.0	12	60.0
9.	8.0	19	152.0
10.	6.0	12	72.0
11.	11.0	28	308.0
12.	10.0	16	160.0
13.	9.0	16	144.0
14.	10.0	25	250.0
15.	9.0	17	153.0
16.	10.0	19	190.0
17.	9.0	19	171.0
18.	10.0	18	180.0
19.	8.0	12	96.0
20.	9.0	20	190.0

The correlation coefficient values (Table 4) indicated that out of four extractants used, three were found to be promising as the amount of Zn extracted by them significantly and positively correlated with dry matter yield. Naik and Das (2010) reported such significant positive correlation between DTPA-CaCl2 extractable Zn and dry matter yield. On the basis, 0.1N HCl was found to be unsuitable extractant for these soils. It is noteworthy that DTPA-$CaCl_2$, DTPA-NH_4HC0_3, EDTA $(NH_4)_2CO_3$ extractable Zn contents were significantly correlated not only with yield but also with zinc uptake by paddy plants.

Table 4: Coefficient of correlation between soil test values obtained by different extraction procedures and uptake of Zn dry matter yield of paddy

Extractants	Zinc	
	Uptake	Yield
EDTA-$(NH_4)_2CO_3$	0.83**	0.81**
DTPA-NH_4HCO_3	0.82**	0.82**
0.1N HCl	0.39*	0.38*
DTPA- $CaCl_2$	0.79**	0.84**

The plot of dry matter yield against DTPA-$CaCl_2$, DTPA-NH_4HC0_3 and EDTA-$(NH_4)_2CO_3$ extractable soil zinc and zinc concentration in paddy plants by the method of Cate and Nelson (1965) indicated 0.53, 0.52, 1.0 and 18.0, mg kg^{-1} as the critical concentration of zinc in soil and plant, respectively (Fig. 1 and 2), below which the response to Zn application can be expected. This value of Zn content in paddy is very close to the critical zinc concentration in rice as reported by Spalbar *et al.* (2017) and Mahata *et al.* (2013) and Muthukumararaja and Sriramachandra.sekharan (2012).

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