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Comparing the extractability of different extractants for zinc in West Bengal

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Abstract
A greenhouse experiment for evaluating the extractability of four different extractants for soil available zinc (Zn) was conducted at the Central Research Farm of Bidhan Chandra Krishi Viswavidyalaya (BCKV) at Gayeshpur, Nadia during 2014 with soils from five blocks of Nadia district, West Bengal. Soils were analysed for zinc (Zn) using the extractants namely DTPA, AB-DTPA, 0.05 *M* HCl and Mehlich 3 (rice variety, Satabdi- 4786 was used as the test crop) with two levels of Zn (0 and 5 kg ha^{-1}). Important physico-chemical properties of soil like pH, organic carbon, textural class, $CaCO_3$ content, clay content, CEC, etc. were analyzed. Amount of Zn as extracted by Mehlich 3 and 0.05 *M* HCl were significantly and positively correlated (r = 0.992**). Mehlich 3 accounted for the highest extractability of soil zinc followed by 0.05 *M* HCl.

Keywords: Zinc, extractant, greenhouse, rice, DTPA, Mehlich 3

Introduction
Zinc (Zn) deficiency is prevalent worldwide in temperate and tropical climates (Fageria *et al*. 2003; Slaton *et al*. 2005) [1, 2]. Rice is the staple food for more than half of the world population and it provides 21% and 15% per capita of dietary energy and protein, respectively (Maclean *et al*. 2002) [3]. Zn deficiency continues to be one of the key factors in determining rice production in several parts of the country (Chaudhary *et al*. 2007) [4]. Several methods for assessment of zinc status in soils are available. Although most soil testing laboratories use DTPA (diethylene triamine penta acetic acid) extractant (Lindsay and Norvell, 1978) [5] for estimating available Zn in the soil, multinutrient extractants like Mehlich 3 (Mehlich, 1984) [6] and ammonium bicarbonate-DTPA (AB-DTPA) (Soltanpour and Schwab, 1977) [7] are also used since these extractants simultaneously extract several nutrients (macro and micronutrients) including Zn (Martens and Lindsay, 1990; Beegle and Oravec, 1990) [8, 9]. Using a single extracting solution for extraction of multiple elements reduces the cost of labour and reagents. Each extractant function with different extracting principles. Acid extractant are based on lowering the pH and the consequent solubilisation of some compounds containing these elements. Chelating extractants on the other hand, have the capacity of reducing the activity of dissolved metals, resulting in release of more soluble compounds in buffered pH (Motta *et al*. 2007) [10]. Many chemical solutions have been evaluated in the search for a universal extractant to predict zinc availability in soil. The extracting ability of the different extractants is also influenced by the physico-chemical properties of the soil. The present work is aimed to access the extracting ability of different extractants under the studied soil conditions.

Materials and methods
Collecting soils from rice growing fields (0-15 cm depth) covering five (5) blocks located in Nadia district, a greenhouse experiment was conducted at the Central Research Farm of BCKV at Gayeshpur, Nadia in 2014 by growing rice cultivar (Satabdi- 4786) in *Kharif* season. Each pot was filled up with the collected soil then thoroughly mixed and flooded with water (deionised). General recommended dose of NPK *i.e.* 100:60:60 was given, only the N dose was applied in splits; the first half of N along with full dose of P and K was given at transplanting and remaining half after 45 days of transplanting of the seedlings. Twenty to

Twenty five day old rice seedlings were transplanted. Two doses of Zn *viz.*, 0 and 5.0 kg Zn $ha^{-1}$was applied using $ZnSO_4.7H_20$ each with four (4) replications so the total Number of pots for the green house experiment was forty (40). The soil samples were collected at maximum tillering and harvesting stages. Five initial soil samples were collected from the above sites to analyse the important properties of the representative soils. Physico-chemical properties of the soil like pH, E.C, organic carbon, $CaCO_3$ content, CEC, clay content etc. were analyzed following the standard protocols. The pH of the soil was determined with the method outlined by Jackson 1973. Electrical conductivity (E.C) was measured by using a direct reading conductivity meter (Jackson, 1967). Oxidizable organic carbon (OC) of the soil was determined following the method of Walkley and Black, 1934. Determination of cation exchange capacity of the soils was done by using the procedure given by Schollen Berger and Simons (1945). Amorphous Mn and Al oxides was determined by the procedure given by Mckeague and Day (1966). Clay content of the soils was determined by hydrometer method (Black, 1965). Four different extractants namely at pH = 2.5±0.5) were used for estimating soil available Zn. DTPA Zn were estimated by the procedure given by Lindsay and Norvell (1978) twenty five day old rice seedlings were transplanted. Two doses of Zn *viz.*, 0 and 5.0 kg Zn $ha^{-1}$was applied using $ZnSO_4.7H_20$ each with four (4) replications so the tota5l while AB-DTPA Zn was estimated by the procedure given Soltanpour and Schwab (1977) [7]. 0.05*M* HCl and Mehlich 3 Zn was determined following the estimation method given by Ponnamperuma *et al*. 1981 [17] and Mehlich, 1984 [6] respectively. Zinc concentration in the soil samples were measured by using an Atomic Absorption Spectrophotometer.

Results and Discussion

Extractable Zn in soil

The amount of DTPA, AB-DTPA, 0.05*M* HCl and Mehlich-3 Zn ranged from 1.47-1.94, 01.86-2.23, 2.33-3.49 and 2.52-3.62 mg kg^{-1} with mean values of 1.72, 1.99, 2.77 and 2.89 mg kg^{-1} respectively (Table 1). At maximum tillering stage of rice, the amount of Zn extracted from soils by DTPA, AB-DTPA, 0.05*M* HCl and Mehlich-3 ranged from 1.61-2.11, 1.97-2.33, 2.45-3.64 and 2.62-3.77 mg kg^{-1} with mean values of 1.85, 2.12, 2.91 and 3.00 mg kg^{-1} (Table 2.). Available Zn extracted by DTPA, AB-DTPA, 0.05 *M* HCl and Mehlich-3 from the post-harvest soils ranged from 1.31-1.79, 1.75-2.09, 2.19-3.36 and 2.40-3.46 mg kg^{-1} respectively with mean values of 1.53, 1.86, 2.63 and 2.75 mg kg^{-1} (Table 3). The soil Zn increased with application of Zn fertilizer irrespective of the type of soil and time of collection of soil samples. On application of Zn @ 5 kg ha^{-1}, during the maximum tillering stage the soil Zn extracted with DTPA, AB-DTPA, 0.05*M* HCl and Mehlich-3 ranged from 1.98-2.45, 2.35-2.87, 2.90-4.03 and 3.03-4.10 mg kg^{-1} (Table 2.). However at the harvesting stage the DTPA, AB-DTPA, 0.05 *M* HCl and Mehlich-3 Zn ranged from 1.70-2.22, 2.05-2.48, 2.65-3.67 and 2.75-3.64 mg kg^{-1} (Table 3). Muthukumararaja and Srirama chand rasekharan (2010) also found that application of Zn in rice significantly affected the concentration of Zn in soil that ranged from 0.89 to 1.53 mg kg^{-1} at tillering stage, 0.69 to 1.45 mg kg^{-1} at panicle initiation and 0.66 to 1.24 mg kg^{-1} at harvest. The results also showed that the soil available Zn is relatively higher at the maximum tillering stage than at the harvesting stage. The Mehlich-3 extractant recorded the highest Zn extracting efficiency at both the two stages of soil sample collection. From the four extractants tested Mehlich-3 was the superior and was followed by 0.05 *M* HCl, AB-DTPA and DTPA across any crop growth stages with or without Zn application. Acid extractants could release part of adsorbed Zn particularly from the oxides (Ribeiro-Filho *et al*. 1999) [19] causing increased Zn extraction from soil which is in agreement with Vidal-Vázquez *et al*. 2005 [20] and De Abreu *et al*. 2002. The presence of NH^{4+} ion in Mehlich 3 renders it able to displace exchangeable cations (Fernandez-Marcos et al. 1998) [22]. Dilute acid solutions may only partially solubilise soil Zn while chelating agents reduce their activity in solution by complexation, causing the dissolution of the labile forms of in soils (De Abreu *et al*. 1998) [21].

Relationship between different forms of soil available Zn.

Soil Zn as extracted by Mehlich 3 and 0.05 *M* HCl were highly and significantly correlated with each other which indicated that they could extract Zn from almost similar Zn pools in the soil. Mehlich 3 Zn and 0.05 *M* HCl Zn showed the highest correlation (r=0.992**) as shown in Table 4. The soil Zn extracted by the four extractants were however positively correlated to each other.

Table 1: Physico-chemical properties of the experimental soils

District		**Nadia**						
Soil available Zn	**Sites**	Mitrapur	Radha nagar	Patuli	Palagacha	Gayesh pur	Mean	Range
	pH	5.23	5.66	5.12	6.35	6.43	5.76	5.12-6.43
	EC (dSm^{-1})	0.22	0.14	0.19	0.16	0.12	0.17	0.12-0.22
	Organic carbon (%)	1.23	1.14	0.91	1.20	0.79	1.05	0.79-1.23
	Al- oxides (g kg^{-1})	6.30	4.23	4.65	5.29	3.36	4.77	3.36-6.30
	Mn-oxides (g kg^{-1})	0.44	0.60	0.49	0.67	0.46	0.53	0.44-0.67
	CEC (meq $100g^{-1}$)	24.46	20.47	21.41	18.97	15.38	20.14	15.38-24.46
	Clay (%)	34.44	38.89	32.05	33.73	49.78	37.78	32.05-49.78
	DTPA Zn (mg kg^{-1})	1.94	1.71	1.47	1.88	1.58	1.72	1.47-1.94
	AB-DTPA Zn (mg kg^{-1})	2.23	1.87	1.92	2.08	1.86	1.99	1.86-2.23
	0.05 *M* HCl Zn (mg kg^{-1})	3.49	2.76	2.33	2.52	2.74	2.77	2.33-3.49
	Mehlich 3 Zn (mg kg^{-1})	3.62	2.84	2.52	2.67	2.79	2.89	2.52-3.62

Table 2: Amount of available Zn (mg kg^{-1}) extracted during maximum tillering stage of rice by the four selected extractants

	DTPA Zn		AB-DTPA Zn		0.05*M*HCl Zn		Mehlich 3 Zn	
Sites	Zn_0	Zn_5	Zn_0	Zn_5	Zn_0	Zn_5	Zn_0	Zn_5
Mitrapur	2.11	2.45	2.33	2.87	3.64	4.03	3.77	4.1
Radhanagar	1.84	2.21	1.98	2.44	2.89	3.22	2.87	3.44
Patuli	1.61	2.11	2.13	2.52	2.45	2.9	2.62	3.03
Palagacha	2.04	2.28	2.21	2.56	2.69	3.07	2.79	3.07
Gayeshpur	1.65	1.98	1.97	2.35	2.88	3.26	2.97	3.42
Mean	1.85	2.21	2.12	2.55	2.91	3.30	3.00	3.41
Range	1.61-2.11	1.98-2.45	1.97-2.33	2.35-2.87	2.45-3.64	2.90-4.03	2.62-3.77	3.03-4.10
Zn_0= Zn @ 0 kg ha^{-1}: Zn_5= Zn @ 5 kg ha^{-1}								

Table 3: Amount of available Zn (mg kg^{-1}) extracted during harvesting stage of rice by the four selected extractants

	DTPA Zn		AB-DTPA Zn		0.05*M* HCl Zn		Mehlich 3 Zn	
Sites	Zn_0	Zn_5	Zn_0	Zn_5	Zn_0	Zn_5	Zn_0	Zn_5
Mitrapur	1.79	2.22	2.09	2.48	3.36	3.67	3.46	3.91
Radhanagar	1.50	1.97	1.75	2.17	2.59	3.01	2.71	3.18
Patuli	1.31	1.78	1.80	2.17	2.19	2.65	2.40	2.75
Palagacha	1.72	2.02	1.93	2.29	2.38	2.81	2.54	2.85
Gayeshpur	1.34	1.70	1.75	2.05	2.62	2.95	2.65	3.12
Mean	1.53	1.94	1.86	2.23	2.63	3.02	2.75	3.16
Range	1.31-1.79	1.70-2.22	1.75-2.09	2.05-2.48	2.19-3.36	2.65-3.67	2.40-3.46	2.75-3.64
Zn_0= Zn @ 0 kg ha^{-1}: Zn_5= Zn @ 5 kg ha^{-1}								

Table 4: Dynamics between available Zn as extracted by the four extractants

Dtpa Zn		AB-Dtpa Zn	0.05 *M* Hcl Zn	Mehlich 3 Zn
DTPA Zn	1.00			
AB-DTPA Zn	0.83	1.00		
0.05 M HCl Zn	0.67	0.66	1.00	
Mehlich 3 Zn	0.69	0.73	0.992**	1.00
**Correlation is significant at the 0.01 level (2-tailed).				

Conclusion

From the results we found that application of Zn increased the soil available Zn irrespective of the stage of soil sample collected or extractant used. Mehlich 3 recorded the highest extractability while DTPA extractant extracted the least amount of soil Zn. The relationship between soil Zn as extracted by the various extractants showed positive correlations; Mehlich 3 Zn and 0.05 *M* HCl Zn showed the highest positive correlation.

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