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Critical limit of zinc for response of rice to zinc application in acidic soils of Assam

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ABSTRACT

Pot culture experiment was conducted with twenty five georeferenced bulk surface soil samples (0-30 cm) having variable zinc status and with four levels of zinc viz., 0, 2, 4 and 6 kg Znha-1. The dry matter yield of rice (var-Ranjit) increased significantly over control with rates of zinc application. The highest dry matter yield was recorded in 4 kg Znha^{-1}. Bray's percent yield ranged from 57.18 to 95.7 and the highest Bray's percent yield of 95.7 was observed in the soil having DTPA-Zn of 0.4mgkg^{-1} and the lowest value of 57.18 was observed in the soil with DTPA-Zn of 2.49 mgkg^{-1}.The soils were also extracted by different extractants viz., DTPA, 0.5N HCl, 0.1N HCl, NH_4OAC, EDTA- $(NH_4)_2CO_3$, AB-DTPA, 0.04M EDTA and 2M $MgCl_2$ solution for available Zn, where DTPA showed the highest correlation with all the plant parameters followed by AB-DTPA, 0.05 N HCl and EDTA-$(NH_4)_2CO_3$, 0.04 EDTA and NH_4OAC. The critical limits of DTPA, AB-DTPA 0.5N HCl , EDTA-$(NH_4)_2CO_3$,0.04 M EDTA and NH_4OAC in soil were found to be 1.24,1.74, 1.25, 2.8, , 0.74, 0.9 mg/kg respectively. The critical limit of Zn for rice was 40 mgkg^{-1}.

Key words: *Rice, critical limit, zinc application*

INTRODUCTION

Critical limit of a nutrient in soil refers to a level below which the crop will readily respond to its application. This level varies with crops, soil and the extractants used. Critical levels of micronutrients in soils and plants are a prerequisite to separate deficient from non-deficient soils. Critical limit of DTPA-Zn has been considered universally as 0.6 ppm irrespective of soil and climatic conditions (Lindsay and Norvell, 1978). But works have also been done in many places on critical limits of Zn considering the soil, climate and other factors of the state (Muthukumararaja, 2012 and Mahata et al., 2013; Shahid et al., 2016, 2014). But in Assam, information is still lacking regarding the requirement of Zn for rice cultivation where the crop is widely grown as a monocrop and as rice based sequence.

Besides, several chemical methods have been developed in last few decades but none of them have world wide acceptance due to their inability to extract Zn from different groups of soils under different soils and climatic conditions. The extractability of soil Zn by various chemical reagents is often used for predicting the availability of soil Zn to plants. The amount of Zn extracted from a soil not only varies according to the reagent used, but is also influenced by the physico-chemical properties of the soil (Vijaykumar et al., 2011 and Mustaq et al., 2013). Though DTPA is the most common extractant for extracting Zn, by assessing the extractability of different extractants, it may be possible to choose a suitable extractant for our soil condition which is more efficient in extraction, cheaper, less time consuming and easily available. Studies on Zn in relation to soils of Assam are very meager.

Therefore, the situation justifies a need to determine the critical limit of zinc for rice in acid soils as well as to find out a suitable extractant for Zn for the same soil.

MATERIALS AND METHODS

A pot culture experiment was conducted to evaluate the critical limit of Zn in soils and crop and evaluation of different methods of extraction of Zn. For this study, twenty five georeferenced bulk surface soil samples (0-30 cm) with variable Zn status were collected from rice growing areas of Assam, representing 3 major soil orders *viz.,* Entisol, Inceptisol and Alfisol (Table 1). The soils were air dried, ground and passed through a 2 mm sieve. A portion of the sample was stored for analysis of different physico-chemical properties and Zn fractions of the soils.

With the above mentioned soils the pot culture experiment was conducted under green house in polythene lined pots with rice variety "Ranjit" as test crop. Each pot was filled with 4kg of soil. A basal dose of N, P_2O_5 and K_2O @ 60:20:40 $Kgha^{-1}$ was applied through urea, SSP and MOP. Zn was applied @ 0, 2, 4, 6 $Kgha^{-1}$ as reagent grade heptahydrate zinc sulphate. Each treatment was replicated thrice in a completely randomized design (CRD). Five numbers of twenty three days old seedlings of rice (var Ranjit) were transplanted in each pot and irrigated with deionised water. Two plants from each pot were collected at 55 days growth period washed and rinsed with deionised water. This stage is designed for nutrient diagnosis and efficient nutrient management for economic optimum yield (Badole et al., 2001). Rice shoots were dried in a hot air oven at 65^0C and the dry matter yield was recorded. The third leaf of the plant was separated and analyzed for zinc content after digesting in a mixture of 3:1 HNO_3: $HClO_4$ according to the procedure of Jackson (1973) (Sakal et al., 1984; Badole et al., 2001; Sarangi et al., 2016). Zinc was determined in the clear aliquots with Atomic Absorption Spectrophotometer.

Bray's percent yield, Bray's percent concentration and Bray's percent uptake (Bray, 1948) were calculated as under:

Bray's percent yield= (Yield without zinc

Table 1. Details of soil samples collected for pot culture experiment.

SL.No.	Location	Soil order	Latitude	Longitude	Altitude (meters)
1	Dagaon	Inceptisol	260 47 ' 50.6 "	940 10 ' 09.80"	87
2	Upper Deuri Gaon	Inceptisol	260 49 ' 14.2 "	940 07 ' 20.00"	86
3	Dhonkhuloi	Inceptisol	260 48 ' 01.5"	940 03 ' 17.50"	93
4	Gorumora	Inceptisol	260 47 ' 30.6"	940 04 ' 38.80"	90
5	Randhanijan	Inceptisol	260 46 ' 18.63"	940 10 ' 53.20"	88
6	Kathanibari	Inceptisol	260 46 ' 16.36"	940 10 ' 37.80"	91
7	Piracotta	Inceptisol	260 48 ' 20.10"	940 23 ' 12.00"	94
8	Midakhat	Inceptisol	260 50 ' 29.30"	940 25 ' 30.00"	96
9	Jogduar	Inceptisol	260 50 ' 13.50"	940 26 ' 41.70"	94
10	Kaliapani	Inceptisol	260 50 ' 19.00"	940 27 ' 44.30"	96
11	Mudoijan	Inceptisol	260 48 ' 47.10"	940 23 ' 45.10"	94
12	Jajimukh	Inceptisol	260 49 ' 48.90"	940 23 ' 25.50"	92
13	RARS Titabar	Alfisol	260 34 ' 26.70"	940 10 ' 53.00"	98
14	Dihingia	Alfisol	260 34 ' 12.70"	940 11 ' 05.10"	96
15	Madhabpur	Alfisol	260 31 ' 51.70"	940 10 ' 50.00"	97
16	Dholi	Alfisol	260 36 ' 08.60"	940 11 ' 05.90"	95
17	Jalukoni	Alfisol	260 37 ' 21.60"	940 11 ' 01.10"	91
18	Dhekiajuli	Alfisol	260 39 ' 20.20"	940 11 ' 38.40"	89
19	Barpeta	Entisol	260 16 ' 22.45"	900 55 ' 13.27"	45
20	Laholi Ali	Entisol	260 39 ' 20.30"	940 11 ' 38.50"	85
21	Kerela Gaon	Entisol	260 57 ' 22.10"	940 08 ' 31.40"	86
22	Gobinpur	Entisol	260 58 ' 26.90"	940 08 ' 33.63"	87
23	Kharjan	Entisol	260 59 ' 19.80"	940 09 ' 39.90"	90
24	Jengraimukh	Entisol	260 59 ' 19.20"	940 09 ' 40.50"	92
25	Borpomua	Entisol	270 03 ' 55.20"	940 16 ' 57.00"	90

treatment)/(Maximum yield with Zn application)×100

Bray's percent concentration = (Zn concentration without zinc treatment)/(Maximum concentration with Zn application)×100

Bray's percent uptake = (Uptake without zinc treatment)/(Maximum uptake with Zn application)×100

The critical limit of Zn in soil and plant was determined by plotting Bray's percent dry matter yield against soil available Zn and plant tissue Zn concentration respectively, as per procedure of Cate & Nelson (1965).

The soils used in the pot culture study were analysed for their initial available Zn content by extracting with 8 numbers of extractants *viz.,* 0.005 M DTPA, 0.5N HCl, 0.1N HCl, NH_4OAC, EDTA-$(NH_4)_2CO_3$, AB-DTPA, 0.04M EDTA and 2M $MgCl_2$ solution.

RESULTS AND DISCUSSION

Initial soil characteristics

There was considerable variation in the pH of the soils collected from different rice growing areas of Assam (Table 2). The pH of the soils ranged from 4.08 to 6.31 with a mean value of 5.07.The electrical conductivity ranged from 0.02 to 0.07, with a mean value of 0.015. The organic carbon content varied from 0.50 percent to 1.48 percent with a mean value of 0.25 percent. A wide degree of variation of CEC of the soils was observed which ranged from 4.8 to 12.2 cmol (p+) kg^{-1}.Particle size analysis of soils revealed that there is a wide variation in soil texture. The different textural classes were clay, sandy clay loam, loam, silty loam and sandy loam.

Pot culture experiment

The dry matter yield of rice (Table 3) in control pots

Table 2. Physico chemical properties of different rice growing soils of Assam.

S.No.	pH (1:2.5)	EC (dSm^{-1})	OC (%)	CEC ($cmolp+kg^{-1}$)	Sand (%)	Silt (%)	Clay (%)	Texture
1	4.88	0.02	0.69	5.40	52.50	25.00	22.50	scl
2	4.68	0.04	0.96	8.80	55.00	25.00	20.00	scl
3	5.67	0.02	0.97	7.50	49.00	16.50	34.50	sc
4	5.46	0.03	0.99	9.20	53.50	11.50	35.00	sc
5	4.56	0.04	1.39	5.10	56.00	9.00	35.00	sc
6	4.68	0.01	0.90	4.80	46.00	36.00	18.00	l
7	4.93	0.02	0.72	5.90	54.00	26.00	20.00	scl
8	4.50	0.02	0.93	5.10	44.00	39.00	17.00	l
9	4.51	0.03	0.87	8.20	53.00	13.00	34.00	sc
10	5.28	0.04	0.59	4.20	45.00	42.00	13.00	l
11	4.61	0.03	0.90	6.80	55.00	15.00	30.00	scl
12	4.55	0.02	0.80	6.20	53.00	27.00	20.00	scl
13	5.78	0.02	1.03	12.20	11.50	8.50	80.00	cl
14	5.38	0.06	1.48	10.60	21.00	23.00	56.00	cl
15	4.61	0.04	1.05	10.30	27.00	33.00	40.00	cl
16	4.80	0.04	0.58	6.30	61.00	16.00	23.00	scl
17	5.40	0.07	1.00	8.00	48.00	21.00	31.00	c
18	5.08	0.06	0.58	6.50	51.00	23.00	26.00	sc
19	5.55	0.04	0.64	5.20	32.00	65.00	3.00	sil
20	4.83	0.04	0.68	5.80	39.00	65.00	4.00	sil
21	6.14	0.05	1.20	4.90	30.00	59.00	11.00	sil
22	5.98	0.02	0.75	6.00	13.00	78.00	9.00	sil
23	6.31	0.03	0.50	6.70	35.00	50.00	15.00	sil
24	5.96	0.04	0.61	5.00	35.00	56.00	9.00	sil
25	5.86	0.03	0.82	5.40	52.00	32.00	16.00	sl
Mean	5.19	0.03	0.86	6.80	42.86	32.58	24.88	
Range	4.5-6.31	.02-0.07	.50-1.48	4.8-12.2	11.5-61	8.5-78	3.0-80	
SD	0.58	0.015	0.25	2.03	13.83	19.50	16.83	

Table 3. Effect of Zn application on dry matter yield of rice (g/pot).

SL No.	DTPA Zn ($mgkg^{-1}$)	Rates of added zinc ($kgha^{-1}$) 0.0	2.0	4.0	6.0	Mean	Bray's percent yield
1	1.21	12.68	12.76	20.65	15.93	15.05	61.40
2	1.01	10.56	11.22	15.46	13.77	12.75	68.30
3	0.54	13.46	18.83	22.13	19.76	18.54	60.82
4	1.80	12.13	13.29	15.40	13.19	13.50	78.76
5	2.49	21.5	23.83	27.14	26.11	24.64	79.21
6	1.10	13.61	15.62	18.81	16.19	16.05	72.35
7	1.45	14.22	13.26	18.22	15.86	15.39	78.04
8	1.80	11.37	12.61	15.15	14.91	13.51	75.04
9	0.61	15.78	15.92	22.58	21.07	18.83	69.88
10	0.40	7.50	8.01	12.14	14.28	10.48	61.77
11	1.32	13.96	17.51	19.19	18.76	17.35	72.74
12	0.91	17.64	18.37	27.64	21.35	21.25	63.81
13	2.54	16.64	19.70	24.31	23.27	20.98	68.44
14	0.62	7.5	8.33	13.10	9.00	9.48	57.25
15	2.10	15.18	16.97	20.65	16.59	17.34	73.51
16	2.22	19.82	20.00	20.70	19.40	19.98	95.74
17	1.41	11.82	13.05	13.24	12.97	12.77	89.27
18	0.41	9.45	12.84	14.58	14.25	12.78	64.81
19	0.52	16.63	17.52	21.36	14.24	17.43	77.85
20	1.20	12.5	15.25	18.55	17.55	15.96	67.38
21	0.80	8.70	10.04	15.09	12.06	11.47	57.65
22	0.52	14.77	18.07	25.83	20.69	19.84	57.18
23	0.41	16.15	17.14	22.92	21.26	19.36	70.46
24	1.20	16.25	17.76	25.15	19.09	19.56	64.61
25	0.62	12.91	15.57	21.98	14.48	16.24	58.73
Mean	1.17	13.71	15.34	19.68	17.04		69.8
Range	0.40 -2.54	7.50 -21.50	8.01-23.83	12.14 -27.64	9.00 -26.11	9.48 -24.64	57.18-95.74
CD (5%)	Zn levels =0.28		Soils = 0.70		Zn x soils =0.24		

varied markedly in different soils and it ranged between 7.5-21.5 g pot^{-1} with a mean value of 13.71 g pot^{-1}. This may be due to the wide variation in the available zinc status of the soils which ranged from 0.4-2.54 $mgkg^{-1}$ with a mean value of 1.17 $mgkg^{-1}$.

The mean dry matter yield of rice increased significantly over control with rates of zinc application, the highest increase was recorded with 4 mg kg^{-1} of applied zinc. Addition of zinc increased dry matter yield to a considerable extent in soils having low available zinc content (0.4 to 0.8 ppm DTPA -Zn).The maximum dry matter yield of 27.64 g pot^{-1} was obtained with application of 4 kg $Znha^{-1}$ which was about 56.69% greater as compared with the treatment that did not receive Zn. This level appeared to be a threshold level as far as grain yield is concerned and further increase in the dose proves detrimental to the crop. Such findings have also been reported by Ghulam et al. (2010) and Sarangi et al. (2016). Fageria et al. (2011) also reported maximum dry matter yield with 5 mg $Znkg^{-1}$ in lowland rice soil. Bray's percent yield ranged from 57.18 - 95.7 depending on the soils under study (Table 3). Response of rice to zinc application in different soil types has been reported by many workers (Reza et al., 2012; Muthukumaraja et al., 2012; Sarangi et al., 2016).

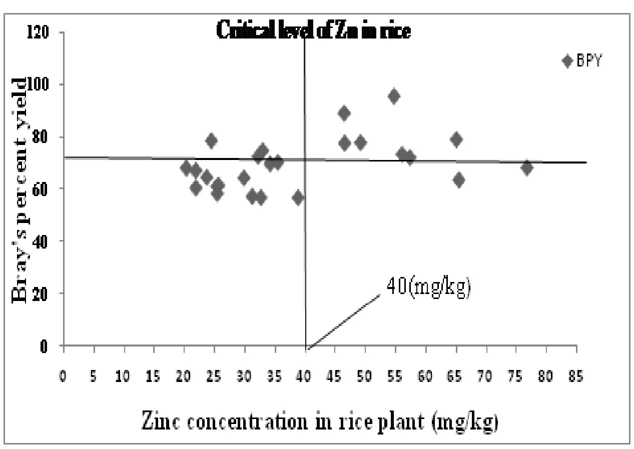

Fig. 1. Critical level of Zn in rice

The Zn concentration of rice plants (Table 4)

Table 4. Effect of Zn application on the Zn conc in rice (mgkg $^{-1}$).

SL No.	DTPA Zn (mgkg^{-1})	Rates of added zinc (kgha^{-1}) 0.0	2.0	4.0	6.0	Mean	Bray's percent Conc.
1	1.21	19.17	26.19	29.73	26.67	25.44	64.47
2	1.01	10.22	20.80	25.66	24.64	20.33	39.83
3	0.54	16.90	22.01	26.27	22.46	21.91	64.31
4	1.80	21.30	24.62	27.93	24.07	24.48	76.24
5	2.49	52.15	68.84	70.96	68.65	65.15	73.49
6	1.10	49.95	59.27	62.21	58.30	57.43	80.3
7	1.45	37.98	51.39	55.03	52.56	49.24	69.01
8	1.80	28.86	33.22	35.70	34.23	33	80.85
9	0.61	28.87	34.64	37.28	36.14	34.23	77.45
10	0.40	19.00	25.70	30.25	27.73	25.67	62.83
11	1.32	26.66	32.86	36.51	32.90	32.23	73.02
12	0.91	44.37	70.72	75.26	71.93	65.57	58.96
13	2.54	57.65	81.89	85.62	82.36	76.88	67.34
14	0.62	23.74	33.16	37.69	36.21	32.7	63.00
15	2.10	51.37	55.94	59.93	57.28	56.13	85.71
16	2.22	44.68	55.98	60.20	58.35	54.8	74.23
17	1.41	42.57	45.56	49.66	48.25	46.51	85.73
18	0.41	15.46	24.98	28.09	26.35	23.72	55.05
19	0.52	29.13	52.38	54.44	50.49	46.61	53.50
20	1.20	16.00	21.68	26.08	23.84	21.9	61.32
21	0.80	25.94	30.67	35.12	33.36	31.27	73.87
22	0.52	22.63	43.57	45.94	43.38	38.88	49.25
23	0.41	16.94	38.93	43.70	42.39	35.49	38.77
24	1.20	24.15	29.92	33.55	31.91	29.88	71.98
25	0.62	18.22	25.77	30.54	27.28	25.45	59.66
Mean	1.17	29.76	40.43	44.13	41.67		66.41
Range	0.40 -2.54	10.22 - 57.65	20.80 - 81.89	25.66-85.62	22.46-82.36		38.77-85.73
CD (0.05%)		Zn levels = 0.22		Soils = 0.57	Zn x soils = 0.19		

in the control pots (Zn_0) varied from 10.22 - 57.65 mg kg^{-1}. The variations in the dry matter yield of rice in different soils were therefore mainly due to the variation in the Zn content of the plant. It finds support from the significant positive correlation between Zn concentration in the plant and dry matter yield (r = 0.578**). Also significant positive correlation between soil available Zn and Bray's percent yield of rice (r = 0.599**) (Table 8) clearly indicate the dependence of yield on the supply of Zn from soil. The variations in the dry matter yield of rice in different soils were therefore mainly due to the variation in the Zn content of the plant. It finds support from the significant positive correlation between Zn concentration in the plant and dry matter yield (r = 0.578**).

The Zn uptake in control pots (Table 5) varied from 0.11-1.12 mg per pot with a mean value of 0.43 mg per pot. The marked variation in Zn uptake by plant in different soils was due to the variation in dry matter yield as well as their Zn concentration. Zn uptake by plants was lower in soils with low levels of Zn as compared to soils with moderate to adequate quantities of available Zn.

Evaluation of methods

Evaluation of soil tests as a measure of Zn availability was carried out by crop response in terms of Bray's percent yield, Bray's percent concentration and Bray's percent uptake and correlation co-efficient were worked out between Zn extracted by different methods and these plant parameters (Table 7). The correlation co-efficient values of different extractants with the plant parameters indicated that 0.005 M DTPA extractable Zn had the highest correlation with Bray's percent yield (r = 0.599**), Bray's percent concentration (r = 0.560**) and Bray's percent uptake (r = 0.397*), followed by AB-DTPA with correlation co-efficient of Bray's percent yield (r = 0.591**), Bray's percent

Table 5. Effect of Zn application on the uptake of Zn by rice (mg/pot).

SL No.	DTPA Zn (mg/kg)	Rates of added zinc (kgha^{-1})				Mean	Bray's percent uptake
		0.0	2.0	4.0	6.0		
1	1.21	0.24	0.33	0.61	0.42	0.40	39.59
2	1.01	0.11	0.23	0.40	0.34	0.27	27.21
3	0.54	0.23	0.41	0.58	0.44	0.42	39.11
4	1.80	0.26	0.33	0.43	0.32	0.33	60.05
5	2.49	1.12	1.64	1.93	1.79	1.62	58.22
6	1.10	0.68	0.93	1.17	0.94	0.93	58.10
7	1.45	0.54	0.68	1.00	0.83	0.76	53.86
8	1.80	0.33	0.42	0.54	0.51	0.45	60.68
9	0.61	0.46	0.55	0.84	0.76	0.65	54.13
10	0.40	0.14	0.21	0.37	0.40	0.28	38.82
11	1.32	0.37	0.58	0.70	0.62	0.57	53.12
12	0.91	0.78	1.30	2.08	1.54	1.42	37.63
13	2.54	0.96	1.61	2.08	1.92	1.64	46.09
14	0.62	0.18	0.28	0.49	0.33	0.32	36.07
15	2.10	0.78	0.95	1.24	0.95	0.98	63.01
16	2.22	0.89	1.12	1.25	1.13	1.10	71.07
17	1.41	0.50	0.59	0.66	0.63	0.60	76.54
18	0.41	0.15	0.32	0.41	0.38	0.31	35.68
19	0.52	0.48	0.92	1.16	0.72	0.82	41.65
20	1.20	0.20	0.33	0.48	0.42	0.36	41.32
21	0.80	0.23	0.31	0.53	0.40	0.37	42.59
22	0.52	0.33	0.79	1.19	0.90	0.80	28.16
23	0.41	0.27	0.67	1.00	0.90	0.71	27.32
24	1.20	0.39	0.53	0.84	0.61	0.59	46.51
25	0.62	0.24	0.40	0.67	0.39	0.43	35.04
Mean	1.17	0.43	0.66	0.91	0.74		47.68
Range	0.40 -2.54	0.11-1.12	0.21-1.64	0.37-2.08	0.32-1.92		27.21-76.54
CD (0.05%)		Zn levels = 0.01		Soils = 0.03		Zn x soils = 0.01	

concentration (r = 0.422*) and Bray's percent uptake (r = 0.398*). Muthukumaraja et al. (2012) also found highest significant and positive correlation of DTPA with Bray's percent yield (r = 0.623** and r = 0.833**), Bray's percent concentration (r = 0.779* and r = 0.802**) and Bray's percent uptake (r = 0.716** and r = 0.847**), respectively in both Vertisol and Entisol. A significant positive correlation of DTPA-Zn with Bray's percent yield (r = 0.496**) and zinc concentration in 3rd leaf (r = 0.943**) was observed by Mahata et al. (2013).

In view of the highest correlation of DTPA extracted Zn with Bray's percent yield (0.599**), Bray's percent concentration (0.560**) and Bray's percent uptake (0.397*) as well as the convenience of determining Zn in the same extract used for other cations,0.005 M DTPA has the greatest possible applicability to measure the available Zn status of the acidic soils of Assam. However, the study also revealed that 0.05M HCl showed the second highest correlation with Bray's percent yield (0.575**), Bray's percent concentration (0.541**) and Bray's percent uptake (0.369), so dilute hydrochloric acid may equally be used in situations where only zinc is to be extracted because the methods listed above consume too much labour, time or chemicals some of which are toxic, expensive and not available easily. But dilute hydrochloric acid is inexpensive, is readily available and not toxic. Besides it gives clear odourless filtrates that are easy to use in atomic absorption spectrophotometers. Katyal and Ponnamperuma (1974) reported that extraction with 0.05M HCl was rapid, inexpensive and convenient soil test for available zinc and set the critical deficiency limit at 1.0 ppm (mgkg^{-1}), which is also close to the result of the present study which was found to be 1.25 ppm (mgkg^{-1})

Critical level of available Zn in soils

Critical levels of available Zn were worked out for the extractants under study according to Cate and Nelson's

Table 6. Available zinc (mgkg^{-1}) extracted by different methods from surface soils.

SL. No.	0.005 M DTPA	0.05N HCl	O.1N HCl	1 N NH_4OAC	EDTA-AC (pH 8.6)	AB-DTPA	2 N MgCl2	0.04 M EDTA
1	1.21	1.29	3.60	0.60	2.87	1.31	0.21	0.45
2	1.01	1.20	5.40	0.50	2.43	1.16	0.34	0.47
3	0.54	0.21	4.80	0.35	1.12	1.31	0.32	0.45
4	1.80	1.70	4.80	1.20	3.07	2.13	0.39	0.87
5	2.49	2.12	5.40	1.10	3.79	2.69	0.21	0.69
6	1.10	2.21	5.60	0.95	3.31	3.19	0.22	0.90
7	1.45	3.54	5.20	1.20	4.15	2.10	0.45	1.20
8	1.80	2.02	6.50	1.85	3.13	2.74	0.53	1.30
9	0.61	1.28	3.30	0.40	1.69	1.53	0.90	0.56
10	0.40	1.15	2.90	0.70	2.72	1.51	0.50	0.73
11	1.32	2.14	5.80	1.50	2.85	1.51	0.35	1.45
12	0.91	0.54	3.50	0.50	2.80	1.20	0.28	0.22
13	2.54	2.25	5.20	0.40	3.71	3.60	0.22	0.25
14	0.62	1.08	8.80	1.85	2.92	1.48	0.29	0.63
15	2.10	2.68	6.60	1.30	3.75	3.75	0.34	1.20
16	2.22	2.18	5.20	1.50	3.88	3.70	0.54	0.95
17	1.41	1.28	4.80	1.30	3.16	1.69	0.43	1.02
18	0.41	0.91	4.20	0.70	2.67	1.34	0.23	0.32
19	0.52	1.24	4.80	1.85	2.86	2.55	0.15	0.84
20	1.20	0.66	4.90	0.75	2.21	2.46	0.32	0.25
21	0.80	0.56	4.10	0.85	2.07	1.45	0.29	0.65
22	0.52	0.35	7.20	0.98	2.87	1.51	0.31	0.62
23	0.41	0.65	3.30	0.65	1.17	2.01	0.36	0.55
24	1.20	1.81	4.30	0.85	1.84	1.48	0.32	0.57
25	0.62	0.74	4.20	0.90	2.82	1.12	0.19	0.65
Mean	1.17	1.43	4.97	0.99	2.79	2.02	0.35	0.71
Range	0.4-2.54	0.21-3.54	2.9-8.80	0.35-1.85	1.12-4.15	1.12-3.75	0.15-0.90	0.22-1.45

Table 7. Coefficients of correlation between available Zn extracted by different methods.

Sl. No.	Plant Parameters	Methods							
		0.005 M DTPA	0.05N HCl	0.1N HCl	Neutral N NH_4OAC	EDTA-Ammonium Carbonate	AB-DTPA	2N $MgCl_2$	EDTA
1	Bray's percent yield	0.599**	0.575**	0.299	0.441*	0.492*	0.591**	0.294	0.526**
2	Bray's percent concentration	0.560**	0.541**	0.377	0.436*	0.408*	0.422*	0.358	0.544**
3	Bray's percent uptake	0.397*	0.369	0.134	0.460*	0.364	0.398*	-0.163	0.275

Table 8. Critical levels of Zn in soils with different extractants.

S.No.	Soil test method	Critical level (mg kg^{-1})
1	0.005 M DTPA	1.24
2	0.05N HCl	1.25
3	1 N NH4OAC	0.9
4	EDTA- $NH_4(CO_3)_2$	2.8
5	AB-DTPA	1.74
6	EDTA	0.74

(1971) graphical method. The critical values below which soils are expected to give response to added Zn varied appreciably for different extractants (Table 8) because of differential extracting power of each extractant. However, the critical limits of 0.1 N HCl and 2 N$MgCl_2$ methods have not been reported because available Zn extracted by these two methods was not correlated with plant parameters.

On the basis of the experimental findings it can be concluded that the critical value of DTPA-Zn in soil and third leaf of rice plant was 1.24 mg kg^{-1} and 40 mg kg^{-1} respectively. From the response of rice to Zn application, it is suggested that Zn @ 4 Kgha^{-1} need to be applied for optimum yield of rice. Various combinations of extracting agents and salts with variation in concentration of chelating agent, time of shaking, soil to solution ratio and other variables showed DTPA to be the suitable extractant for acidic soils of

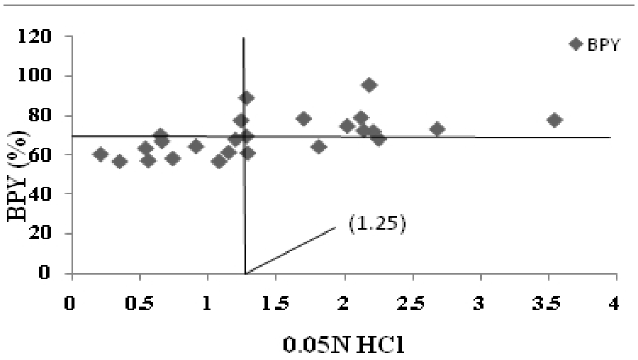

Fig. 2

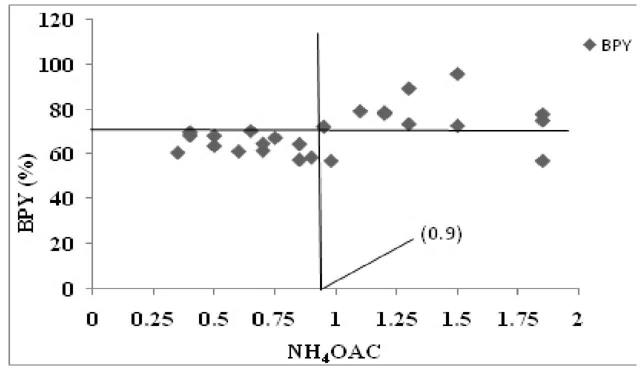

Fig. 3

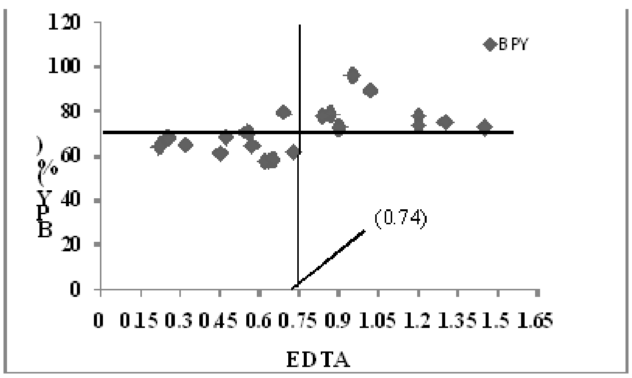

Fig. 4

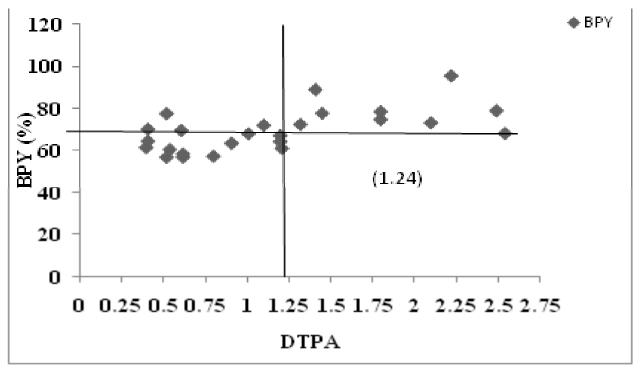

Fig. 5

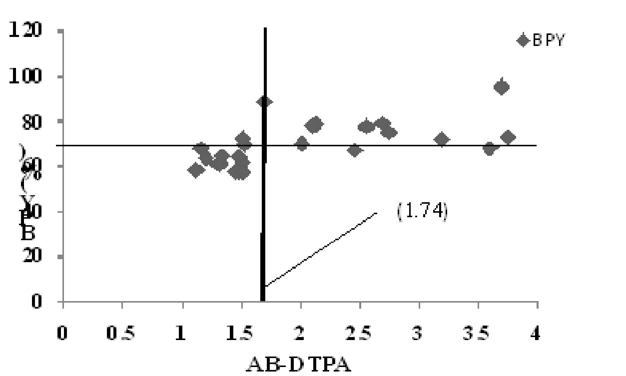

Fig. 6

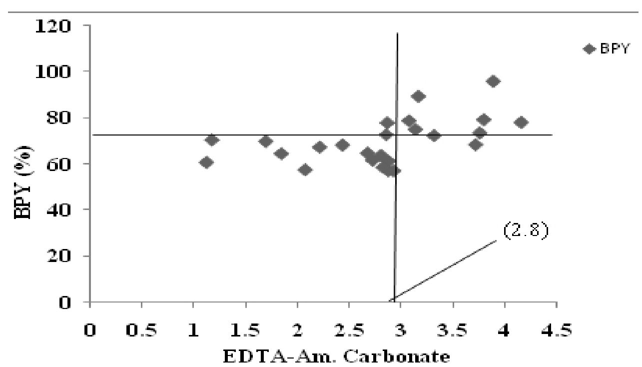

Fig. 7

Fig. 2 - Fig. 7. Scatter diagram showing relationship between different methods of Zn extraction and Bray's percent yield.

Assam. However, 0.05M HCl may equally be used in situations where only zinc is to be extracted because the methods listed in the study consume too much labour, time or chemicals some of which are toxic, expensive and not available easily.

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