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CRITICAL LIMIT OF ZINC FOR RICE SOILS OF VEERANAM COMMAND AREA, TAMILNADU, INDIA

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ABSTRACT

A pot culture experiment was conducted to determine the critical limit of Zn for rice grown in Veeranam command area (Vertisol and Entisol). The soil contained $CaCO_3$ - 0.33-7.54%, pH- 6.2-8.8, EC- 0.27-1.6 dSm^{-1} and organic carbon 2.7-11.4 g kg^{-1}. The available Zn content of soils was estimated by seven extractants and the amount of Zn extracted followed the order of 0.005 M DTPA (pH 7.3) > 0.01 M EDTA +1 M $(NH_4)_2CO_3$ (pH 8.6) > 0.01 M EDTA + TEA (pH 6.7) > 0.01 M EDTA + 1 N NH_4OAC (pH 7.0) >1 N NH_4OAC + 0.01 % Dithizone > 0.01 M EDTA >1 N NH_4OAC (pH 7.0) in both Vertisol and Entisol. The critical levels of DTPA, EDTA +1 M $(NH_4)_2CO_3$, EDTA + TEA, EDTA + 1 N NH_4OAC, NH_4OAC + 0.01 % Dithizone, EDTA, NH_4OAC extractable Zn were found to be 0.85, 0.75, 0.72, 0.70, 0.69, 0.63 and 0.40 in Vertisol and 0.84, 0.82, 0.80, 0.79, 0.78, 0.73 and 0.44 ppm in Entisol and a critical level of 40 ppm and 38 ppm zinc in rice plant for Vertisol and Entisol as determined by both Cate and Nelson's graphical and statistical procedure. The DTPA extractant showed the highest significant and positive correlation with Bray's percent yield, plant Zn content and Zn uptake among the extractants. Hence, the DTPA extractant can be regarded as a good method of determining available Zn status for rice grown in Vertisol and Entisol of Veeranam command area.

Keywords: Rice, soil, critical limit, zinc applications.

INTRODUCTION

Rice is a stable food for about 50 percent of the world's population that resides in Asia, where 90 per cent of the world's rice is grown and consumed. It is an important stable food that provides 66-70 per cent body calorie intake of the consumers [1]. The world paddy production was 614.65 million tonnes in 2004-2005 from an area of 153.51 million ha with an average yield of 3.87 tonnes per ha. In Asia, India has the largest area under rice (44.3 million ha) accounting for 29.4 per cent of the global rice area. Developing countries contribute about 90 per cent of the total world rice production. The yield levels in India are low at 2.04 tonnes per ha compared to other major rice production countries such as Japan (6.52 t/ha), China (6.24 t/ha) and Indonesia (4.25 t/ha). India would need to produce 143 million tonnes of rice to meet the growing population by 2030 [2]. In Tamil Nadu, rice cultivation spreads over an area of 20 lakhs hectares with a total production of 52 lakhs tonnes [3]. Rice is the stable food more than half of the world population. On a global basis, rice provides 21% and 15 % per capita of dietary energy and protein, respectively [4].

Rice (*Oryza sativa* L.) is one of highly sensitive crops to zinc (Zn) deficiency and Zn is the most important micronutrient limiting rice growth and yield [5, 6]. Zinc deficiency in common in rice soils. The availability of Zn in the soil varies widely depending on the soil properties. Zinc contents in soil and leaves of rice were directly related to the increased application of these elements. Nutrients survey conducted by [7] has revealed widespread deficiencies of macro and micro nutrients in major rice producing districts of the Punjab. Zinc deficiency in soils and plants is a global micronutrients deficiency problem reported in many countries and thirty percent of the world soils are zinc deficient [5]. In India 47% of the soils and in Tamilnadu 53% of the soils are found deficient in Zn [8]. 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 the soil fertility class, thus the crop response to added Zn is not always obtained [9]. Critical zinc for rice was (0.74 ± 0.18 ppm) across the soils and agro-ecological regions of India [10]. The critical limits/ levels are quite often employed for a wide variety of soils and crops, even though these critical limits may be different not only for soils, crop species but also for different varieties of a given crop [11]. Twenty three surface soil samples (0-15 cm) in rice growing tracts of Thanjavur district, Tamilnadu was analyzed for zinc and found that available zinc extracted by DTPA varied from 0.52 to 8.4 ppm [12]. Soils with DTPA-Zn less than critical limit gave 82.7% more yield when Zn was applied at 5 mg kg^{-1} and soils with DTPA-Zn more than critical limit recorded only 34.8% yield increase in Meghalaya soils [13]. Veeranam command area is an intensive cultivated area where rice is the predominant crop and critical limit for zinc has not been fixed so far. Hence, an experiment was conducted to determine the critical levels of Zn in soils and plants.

MATERIALS AND METHODS

A pot experiment with rice variety (ADT-43) was conducted during 2009-2010 in the net house of the Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, Chidambaram, and Tamilnadu, India. The 200 surface soil samples (0-15cm) coming under the order Vertisol, Entisol

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and Alfisol were collected from different locations of Veeranam command area. Rice is grown in Vertisol and Entisol.

Out of 200 soil samples, 50 soil samples belonging to Vertisol and Entisol were used in pot experiment. The initial soil samples were analyzed for both mechanical and chemical compositions following standard methods [10]. Soils were analyzed for available zinc by different extract ants (Table-2). There were two Zn treatments viz. 0 and 2.5 ppm (soil basis). Each of the treatments was replicated thrice in a completely randomized design (CRD) to give a total of 6 (2×3) pots for each soil. Thus the total number of earthen pots used in this study was 300 (6×50). An amount of 10 kg of each soil was weighed into a series of 6 pots and three rice seedlings were plated in each pot. The zinc was applied through analytical grade zinc sulphate ($ZnSO_4.7H_2O$). The nutrients N, P_2O_5 and K_2O equivalent to @ 150, 50 and 50 kg ha^{-1} were applied as basal dose through urea, single super phosphate and muriate of potash, respectively to each pot. The soils of all pots were kept moist with addition of distilled water periodically. The plants were cut at the stage of 6 weeks, washed with distilled water and dried in an oven at $65^{\circ}C$ for 24 hours. The extractable Zn content of soil and Zn content of plant in the digest were determined directly by atomic absorption spectrophotometer and Zn uptake was computed.

The critical level of Zn in soil and rice plant was determined by following two approaches graphical and statistical proposed by [14]. In this procedure, a scatter diagram of the Bray's per cent yield on Y- axis versus soil test values on X- axis was plotted. For evaluation of different extract ants, the co-efficient of correlation between amount of zinc extracted by different extract ants with bray per cent yield, tissue zinc concentration and uptake of zinc by rice crop were worked out. Bray percent yield was calculated by using the formula.

$$\text{Bray percent yield} = \frac{\text{Yield without zinc} \times 100}{\text{Yield at optimum zinc}}$$

RESULTS AND DISCUSSIONS

Initial soils characteristics

The experimental soils had pH ranging from 6.2-8.8 (slightly acidic to strongly alkaline) with mean of 7.6, EC ranging from (0.27-1.6 dSm^{-1}) with mean of 0.76 dSm^1, Organic carbon ranging from (2.7-11.4 g kg^{-1}) with mean of 7.56 g kg^{-1}, $CaCO_3$ ranging from (0.33-7.54%) with mean of 1.96 %, (Table-1a) The available N ranging from (213.8-391.2 kg ha^{-1}) with mean of 313.8 kg ha^{-1}, P ranging from (19-54 kg ha^{-1}) with mean of 33.7 kg ha^{-1} and K ranging from (147-366 kg ha^{-1}) with mean of 281.4 kg ha^{-1}. The DTPA-extractable Zn varied from (0.48-1.90 mg kg^{-1}) with mean of 0.79 mg kg^{-1}. The texture of the soil was clay loam, silt clay loam, sandy clay loam and clayey (Table-1b).

Dry matter yield, Zn content and uptake

Rice plants significantly responded to Zinc application in all the soils (Table-3) The Dry matter production in Zn treated pots ranged from 22.5-53.9 g with mean value of 34.71 g. The DMP in Zn control pot ranged from 15.3-38.7 g with mean value of 24.89g. DMP improved drastically to Zn applied in soils which were low in zinc content compared to high Zn content soils. The plant zinc content and uptake were significantly influenced in both soils where Zn was applied at the rate 2.5 ppm. The plant Zn content in Zn treated pot ranged from (25.5-83.1 ppm) with mean value 47.4 ppm and in control pot Zn content ranged from (19.3 - 36.5 ppm) with mean value of 28.08 ppm. The Zn uptake in Zn treated pots ranged from (0.88-2.99 mg/pot) with mean value of 1.60 mg /pot, while in control pot, Zn uptake ranged from (0.36-1.21 mg/pot) with mean value of 0.69 mg/pot. The Bray percent yield ranged from (50.9- 94.7%) with mean value of 72. %. The similar results have been reported earlier [9].

Evaluation of different extractants

The zinc extracted by different extractants differs significantly among the soils (Table-4). The Zn extracted by DTPA ranged from (0.48-1.8 and 0.53-2.48 ppm) with mean value of (0.86 and 0.96 ppm), EDTA +1 M $(NH_4)_2CO_3$ (0.58-1.02 and 0.65-1.86 ppm) with mean value of 0.76 and 0.91ppm, EDTA + TEA (0.42-0.93 and 0.49-0.93 ppm) with mean value of 0.69 and 0.72, EDTA + 1 N NH_4OAC (0.39-0.96 and 0.53-1.40 ppm) with mean value of 0.69 and 0.78, 1 N NH_4OAC + 0.01 % Dithizone (0.36-1.06 and 0.41-1.26 ppm) with mean value of 0.56 and 0.69, EDTA (0.36-0.97 and 0.43-0.93 ppm) with mean value of 0.64 and 0.70, 1 N NH_4OAC (0.20-0.63 and 0.28-0.83 ppm) with mean value 0.38 and 0.47 ppm in both Vertisol and Entisol, respectively. Based on the amount of Zn extracted by different extractants, the relative efficiency were of the following order 0.005 M DTPA (pH 7.3) > 0.01 M EDTA +1 M $(NH_4)_2CO_3$ (pH 8.6) > 0.01 M EDTA + TEA (pH 6.7) > 0.01 M EDTA + 1 N NH_4OAC (pH 7.0) >1 N NH_4OAC + 0.01 % Dithizone > 0.01 M EDTA >1 N NH_4OAC (pH 7.0) in both Vertisol and Entisol. The amount of Zn extracted by different extractants were correlated with Bray's percent yield, plant tissue and zinc uptake by rice crop (Table-4) Among the extractants DTPA-Zn correlated the highest with Bray's percent yield ($r = 0.623^{**}$ and $r = 0.833^{**}$) which gave positive and significant relationship as compared to other extractants in both Vertisol and Entisol and also DTPA-Zn recorded higher significant positive correlation with Zn content (0. 779 ** and 0.802 **) and uptake (0.716 ** and 0.847 **), respectively in both Vertisol and Entisol. Hence DTPA- Zn can be considered as the best Zn extractant for influencing available Zn in soils. The DTPA extractable Zn varied from 0.30 to 1.60 mg kg^{-1} in soils of Agra district [15].

Critical level of zinc

The critical limits for soil zinc extracted by 0.005 M DTPA, 0.01 M EDTA+1 M $(NH_4)_2CO_3$, EDTA + TEA,

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EDTA + 1 N NH_4OAC, NH_4OAC + 0.01% Dithizone, EDTA and neutral N NH_4OAC solution in both Vertisol and Entisol worked out to be 0.85 ppm, 0.75 ppm, 0.72 ppm, 0.70 ppm, 0.69 ppm, 0.63 ppm and 0.40 ppm in Vertisol (Figure-1a,g) and 0.84 ppm, 0.82 ppm, 0.80 ppm, 0.79 ppm, 0.78 ppm, 0.73 ppm and 0.44 ppm in Entisol (Figure-2a,g). The critical levels of Zn were fixed following the procedure of [14] both graphical and statistical. Form the correlation coefficient between Zn extractants and Bray percent yield, the critical levels of 0.85 ppm and 0.84 ppm obtained with DTPA-Zn is the critical levels of Zn for rice soils of Veeranam command area. A critical level of 40 ppm and 38 ppm zinc in rice plant for Vertisol and Entisol (Figure-3a, b) were obtained on the basis of response to zinc at tillering and flowering stage of the crop [16] reported that both graphical and statistical methods indicated 0.76 ppm as the critical value of Zn deficiency soils. Critical limit of wetland rice soils of Meghalaya for DTPA extractable Zn was 1.2 mg kg^{-1} for soil and 35.9 mg kg^{-1} in rice plant [13] the critical limit for DTPA-Zn was 0.75 ppm and 20.02 ppm in rice plant of deltaic rice soils of Andhra Pradesh [17]. Both graphical and statistical methods indicated critical limits of Zn for DTPA, HCl and NH_4OAC (0.83, 2.6 and 0.26 ppm) and (0.83, 1.8 and 0.40 ppm) in rice, respectively [9].

Table-1(a). Initial characteristics of experimental soil.

Soil (location)	**Soil series**	**Textural Class** (USDA)	**pH**	**Ec** (dSm^{-1})	**Organic carbon** ($g\ kg^{-1}$)	**$CaCO_3$** (%)
Vertisol						
Annamalainagar	Kondal	Clay loamy	8.6	0.83	4.2	1.23
C. Alambadi	Kondal	Clay	7.9	0.58	9.4	1.10
Kannankudi	Kondal	Clay	7.6	1.00	5.1	0.75
Kodiyalam	Kondal	Clay loam	8.2	1.23	7.4	2.50
Kelakarai	Kondal	Clay	7.9	0.32	8.5	2.60
Kodiballam	Kondal	Clay loam	8.3	0.56	5.5	1.34
Kumaramangalam	Kondal	Clay loam	8.5	0.73	9.6	0.99
Laalpuram	Kondal	Clay loam	7.5	0.86	9.2	2.34
Manalur	Kondal	Clay loam	7.4	0.69	9.2	0.96
Meedhikudi	Kondal	Clay	7.8	0.79	6.3	4.63
Nakkaravaradhankudi	Kondal	Clay	7.9	0.83	6.3	1.23
Parangipettai	Kondal	Silt clay loam	8.8	0.31	2.7	0.99
Savarajanpettai	Kondal	Clay loam	8.2	0.56	9.3	0.77
Sivakkam	Kondal	Clay	8.3	0.76	6.3	0.98
Thunisiramedu	Kondal	Clay	7.5	0.81	9.4	2.56
Veyyalur	Kondal	Clay loam	8.6	0.85	5.5	3.10
Vasapudhur	Kondal	Clay	7.9	0.55	6.0	0.95
Vadamur	Kondal	Clay	8.3	0.63	3.6	1.20
Radhvilagam	Adanur	Clay	8.1	0.93	3.6	0.79
Kovilampoondi	Adanur	Clay	7.7	0.76	10.1	7.54
Pinnathur	Adanur	Clay	8.0	0.80	5.8	1.01
Uthamacholamangalam	Adanur	Clay loam	7.5	0.56	6.3	6.34
Thillainayagapuram	Adanur	Clay	7.8	0.64	5.8	6.45
Entisol						
Maduvankarai	Padugai	Silt clay loam	7.8	0.80	9.3	0.33
K.Moongailaadi	Padugai	Sandy clay loam	6.5	0.92	8.9	1.10
Therkumangudi	Padugai	Sandy clay	8.3	0.54	6.3	1.34

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		loam				
Melbhuvanagir	Padugai	Sandy clay loam	7.0	0.84	8.9	1.52
Orathur	Padugai	Sandy clay loam	6.9	1.06	6.1	0.76
Karuppur	Padugai	Sandy clay loam	8.7	1.20	10.4	0.86
Nanjaimegathuvazkkai	Padugai	Sandy clay loam	7.0	0.71	6.3	0.99
A. Thivaraganatham	Padugai	Sandy clay loam	6.9	0.54	11.4	3.23
Azhichikudi	Padugai	Sandy clay loam	7.5	0.50	8.4	5.06
Miralur	Padugai	Sandy clay loam	7.8	0.48	8.3	0.78
Sathiyathoppu	Padugai	Sandy clay loam	6.9	0.82	10.5	0.88
Suthukuzhi	Padugai	Sandy clay loam	7.6	0.81	10.7	2.43
Vandurayanpettai	Padugai	Sandy clay loam	7.3	0.83	8.7	3.43
Vattarayannettu	Padugai	Sandy clay loam	6.3	0.92	7.9	2.15
Ayyapettai	Padugai	Sandy clay loam	7.8	0.63	7.3	2.36
Kizhiyanoor	Padugai	Sandy clay loam	8.0	0.63	8.2	1.36
Keerapalayam	Padugai	Sandy clay loam	6.9	0.62	7.2	0.96
Kathazhai	Padugai	Sandy clay loam	7.9	1.60	6.8	1.32
Palayamserthangudi	Padugai	Sandy clay loam	7.8	0.92	6.3	0.67
Parathur	Padugai	Sandy clay loam	6.2	0.68	9.2	0.45
Sathamangalam	Padugai	Sandy clay loam	6.3	1.23	8.5	0.55
Vadacharirajapuram	Padugai	Sandy clay loam	7.8	0.55	8.8	1.30
Boothaviayanpettai	Padugai	Sandy clay loam	6.3	1.03	8.5	0.96
Kilavaddikathan	Padugai	Sandy clay loam	7.9	0.91	8.1	1.12
Vadakkumarangudi	Padugai	Sandy clay loam	7.8	1.20	7.8	4.53
Adhivaraganallur	Padugai	Silt clay loam	8.4	0.63	7.0	3.43
Keelbhuvanagiri	Padugai	Sandy clay loam	8.3	0.27	7.9	0.45
Range			**6.2-8.8**	**0.27-1.6**	**2.7-11.4**	**0.33-7.54**
Mean			**7.68**	**0.76**	**7.56**	**1.96**

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Table-1(b). Initial characteristics of experimental soil.

Soil (location)	**Soil series**	**Textural class** (USDA)	**Available N** (kg ha^{-1})	**Available K** (kg ha^{-1})	**Available P** (kg ha^{-1})	**DTPA extractable zinc** (ppm)
Vertisol						
Annamalainagar	Kondal	Clay loamy	259.3	24	305.6	0.49
C.Alambadi	Kondal	Clay	372.0	38	312.4	0.78
Kannankudi	Kondal	Clay	295.3	38	265.4	0.48
Kodiyalam	Kondal	Clay loam	350.0	52	326.0	0.56
Kelakarai	Kondal	Clay	354.0	30	285.0	0.96
Kodiballam	Kondal	Clay loam	352.0	38	322.1	0.91
Kumaramangalam	Kondal	Clay loam	302.6	37	294.3	0.49
Laalpuram	Kondal	Clay loam	365.0	30	265.0	1.01
Manalur	Kondal	Clay loam	302.1	37	318.4	0.63
Meedhikudi	Kondal	Clay	254.3	28	352.0	1.76
Nakkaravaradhankudi	Kondal	Clay	319.7	32	340.6	1.67
Parangipettai	Kondal	Silt clay loam	296.0	23	181.5	0.67
Savarajanpettai	Kondal	Clay loam	312.0	36	285.4	1.31
Sivakkam	Kondal	Clay	317.3	40	278.6	0.63
Thunisiramedu	Kondal	Clay	365.2	31	269.2	0.84
Veyyalur	Kondal	Clay loam	302.6	46	268.3	0.63
Vasapudhur	Kondal	Clay	362.0	43	302.6	0.84
Vadamur	Kondal	Clay	362.1	39	296.1	0.63
Radhvilagam	Adanur	Clay	350.2	31	236.5	0.65
Kovilampoondi	Adanur	Clay	286.0	42	302.1	1.23
Pinnathur	Adanur	Clay	291.2	36	326.1	0.76
Uthamacholamangalam	Adanur	Clay loam	286.2	38	280.1	1.84
Thillainayagapuram	Adanur	Clay	391.2	19	297.4	0.52
Entisol						
Maduvankarai	Padugai	Silt clay loam	319.2	26	280.1	0.67
K.Moongailaadi	Padugai	Sandy clay loam	213.8	49	318.0	0.56
Therkumangudi	Padugai	Sandy clay loam	290.1	36	296.7	0.58
Melbhuvanagir	Padugai	Sandy clay loam	324.8	38	362.5	0.65
Orathur	Padugai	Sandy clay loam	318.1	30	283.1	0.58
Karuppur	Padugai	Sandy clay loam	276.8	54	268.4	0.63
Nanjaimegathuvazkkai	Padugai	Sandy clay loam	295.0	28	336.2	0.68
A. Thivaraganatham	Padugai	Sandy clay loam	347.0	21	315.4	0.74
Azhichikudi	Padugai	Sandy clay loam	362.1	31	278.0	0.72

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Miralur	Padugai	Sandy clay loam	296.8	29	301.7	0.71
Sathiyathoppu	Padugai	Sandy clay loam	266.8	19	286.4	0.58
Suthukuzhi	Padugai	Sandy clay loam	300.3	30	265.1	0.89
Vandurayanpettai	Padugai	Sandy clay loam	318.3	26	238.3	0.67
Vattarayannettu	Padugai	Sandy clay loam	365.3	32	366.0	0.81
Ayyapettai	Padugai	Sandy clay loam	324.8	26	283.4	1.9
Kizhiyanoor	Padugai	Sandy clay loam	308.4	34	293.0	0.53
Keerapalayam	Padugai	Sandy clay loam	215.6	31	147.5	0.76
Kathazhai	Padugai	Sandy clay loam	362.2	37	354.7	0.58
Palayamserthangudi	Padugai	Sandy clay loam	300.1	27	283.1	0.72
Parathur	Padugai	Sandy clay loam	362.1	31	202.4	0.63
Sathamangalam	Padugai	Sandy clay loam	291.4	25	234.0	0.58
Vadacharirajapuram	Padugai	Sandy clay loam	324.7	33	195.1	0.66
Boothaviayanpettai	Padugai	Sandy clay loam	282.0	29	226.3	0.67
Kilavaddikathan	Padugai	Sandy clay loam	320.8	40	286.2	0.78
Vadakkumarangudi	Padugai	Sandy clay loam	268.0	21	178.4	0.59
Adhivaraganallur	Padugai	Silt clay loam	326.9	31	280.6	0.76
Keelbhuvanagiri	Padugai	Sandy clay loam	267.1	20	199.6	0.78
Range			**213.8-391.2**	**19-54**	**147.5-366**	**0.48-1.90**
Mean			**313.86**	**32.84**	**281.41**	**0.79**

Table-2. List of different extractants used for extraction of available soil zinc.

Name of the Extract ants	**Soil: solution ratio**	**Shaking time** (min.)	**Reference**
0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M TEA (pH 7.3)	1:2	120	18
0.01 M EDTA + M $(NH_4)_2CO_3$ (pH 8.6)	1:2	30	19
0.01 M EDTA + TEA (pH 6.7)	1:2	120	20
0.01 M EDTA + 1 N NH_4OAC (pH 7.0)	1:5	30	21
1 N NH_4OAC + 0.01% Dithizone	1:10	60	22
0.01 M EDTA	1:5	30	23
1 N NH_4OAC (pH 7.0)	1:5	30	24

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

Location	**Dry matter weight** (g/ pot)			**Zn content** (ppm)		**Zn uptake** (mg /pot)	
	Zn^+	**Zn^-**	**Bray's percent yield**	**Zn^+**	**Zn^-**	**Zn^+**	**Zn^-**
				Vertisol			
Annamalainagar	33.4	19.8	59.2	32.5	29.3	1.08	0.58
C.Alambadi	36	20.2	56.1	38.5	30.2	1.38	0.61
Kannankudi	27	21.6	80	42.3	29.8	1.14	0.63
Kodiyalam	38.1	19.6	51.4	63.8	30.1	2.43	0.58
Kelakarai	29.5	19.3	65.4	37.3	30.1	1.1	0.58
Kodiballam	26.5	20.1	75.8	53.1	26.2	1.4	0.52
Kumaramangalam	22.5	20.3	90.2	60.3	25.5	1.35	0.51
Laalpuram	30.2	23.1	76.4	70.3	28.3	2.12	0.65
Manalur	31.1	19.5	62.7	58	27.4	1.8	0.53
Meedhikudi	33	19.3	58.4	64.3	28.6	1.52	0.55
Nakkaravaradhankudi	24.7	23.4	94.7	50	29.3	1.23	0.68
Parangipettai	33.3	24.3	72.9	44.7	30.4	1.48	0.73
Savarajanpettai	32	19.9	62.1	57.3	25.6	1.83	0.5
Sivakkam	34.1	21.3	62.4	40.7	25.6	1.38	0.54
Thunisiramedu	29.3	20.4	69.6	50.3	29.3	1.47	0.59
Veyyalur	25.5	23.1	90.5	55.3	30.2	1.41	0.69
Vasapudhur	33.1	25.1	75.8	35.3	27.4	1.16	0.68
Vadamur	29	24.6	84.8	47.5	26.3	1.32	0.64
Radhvilagam	24.3	16.8	69.1	36.3	25.4	0.88	0.42
Kovilampoondi	27.3	15.3	59	42.6	23.6	1.14	0.36
Pinnathur	27.6	16	57.8	63.3	25.5	1.73	0.4
Uthamacholamangalam	33.2	18.2	64.8	47.3	23.1	1.52	0.42
Thillainayagapuram	29.3	19	81.8	37.5	24.4	1.09	0.46
				Entisol			
Maduvankarai	36.4	29.8	79.2	55.6	31.6	2.02	0.94
K.Moongailaadi	38.1	30.2	87.4	66.7	36.4	2.52	1.09
Therkumangudi	33.5	29.3	86.6	75.3	34.8	2.99	1.01
Melbhuvanagir	36	31.2	88.1	83.1	36.3	2.17	1.13
Orathur	34.5	30.4	84.0	63.1	32.5	2.14	0.98
Karuppur	38.2	32.1	77.0	60.3	30.1	2.3	0.96
Nanjaimegathuvazkkai	40.6	31.3	71.7	72.3	36.5	2.93	1.14
A. Thivaraganatham	31.2	22.4	80.5	32.3	24.1	1	0.53
Azhichikudi	43.1	34.7	73.1	30.7	19.6	1.32	0.68
Miralur	41.4	30.3	50.9	25.5	19.4	1.06	0.58
Sathiyathoppu	36.1	18.4	74.1	41.2	20.1	1.48	0.36
Suthukuzhi	30.6	22.7	57.9	30.4	24.8	0.93	0.56

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Vandurayanpettai	34.7	20.1	76.9	38	29.1	1.31	0.58
Vattarayannettu	31.3	24.1	67.7	43.1	30.5	1.33	0.73
Ayyapettai	28.5	19.3	62.6	50.7	32.9	1.44	0.63
Kizhiyanoor	39.4	25	55.1	53.4	25.4	2.1	0.63
Keerapalayam	51.1	28.2	71.8	49.8	34	2.54	0.95
Kathazhai	42.6	30.6	85.3	28.4	19.3	1.2	0.59
Palayamserthangudi	30.7	26.2	70.2	34.7	22.4	1.06	0.58
Parathur	47.1	36.4	86.7	43	32.1	2.02	1.16
Sathamangalam	40.7	35.3	78.4	39.4	34.3	1.6	1.21
Vadacharirajapuram	35.2	27.6	62.6	36.2	28.9	1.27	0.79
Boothaviayanpettai	38.3	24	75.4	44.1	30.1	1.68	0.72
Kilavaddikathan	51.3	38.7	78.9	32.1	25.6	1.64	0.99
Vadakkumarangudi	42.3	33.4	74.1	36	23.2	1.52	0.77
Adhivaraganallur	38.7	28.7	74.9	41.3	30.1	1.59	0.86
Keelbhuvanagiri	53.9	34.3	63.6	36.8	28.7	1.98	0.98
Range	22.5-53.9	15.3-38.7	50.9-94.7	25.5-83.1	19.3- 36.5	0.88-2.99	0.36-1.21
Mean	34.71	24.89	72.31S	47.44	28.08	1.60	0.69

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

Table-4. Zinc extraction and its relationship with bray's percent yield, tissue zinc and uptake (Vertisol and Entisol).

Extractant	**Zinc extracted** (ppm)				**Critical limits in soils**				**Correlation (r) with soil Zinc Flowering stage**			
	Vertisol		**Entisol**		**Vertisol**		**Entisol**		**Vertisol**		**Entisol**	
	Range	**Mean**	**Range**	**Mean**	(ppm)	**Bray's percent yield**	(ppm)	**Bray's percen t yield**	**Tissue Zinc**	**Zinc uptake**	**Tissue Zinc**	**Zinc uptake**
0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M TEA (pH 7.3)	0.48-1.84	0.86	0.53-1.90	0.71	0.85	0.623**	0.84	0.833**	0.779**	0.716**	0.802**	0.847**
0.01 M EDTA + M $(NH_4)_2CO_3$ (pH 8.6)	0.58-1.02	0.76	0.65-1.86	0.91	0.75	0.517*	0.82	0.663**	0.980**	0.915**	0.780**	0.576**
0.01 M EDTA + TEA (pH 6.7)	0.42-0.93	0.69	0.49-0.93	0.72	0.72	0.156*	0.80	0.161*	0.950**	0.969**	0.839**	0.964**
0.01 M EDTA + 1 N NH_4OAC (pH 7.0)	0.39-0.96	0.69	0.53-1.40	0.78	0.70	0.196*	0.79	0.068*	0.969**	0.953**	0.880**	0.834**
1 N NH_4OAC + 0.01% Dithizone	0.36-1.06	0.56	0.41-1.26	0.69	0.69	0.379*	0.78	0.375*	0.969**	0.947**	0.957**	0.584**
0.01 M EDTA	0.36-0.97	0.64	0.43-0.93	0.70	0.63	0.072*	0.73	0.013*	0.962**	0.957**	0.882**	0.968**
1 N NH_4OAC (pH 7.0)	0.20-0.63	0.38	0.28-0.83	0.47	0.40	0.053*	0.44	0.445*	0.967**	0.966**	0.970**	0.917**

** Significant at 1% level, *Significant at 5 % level

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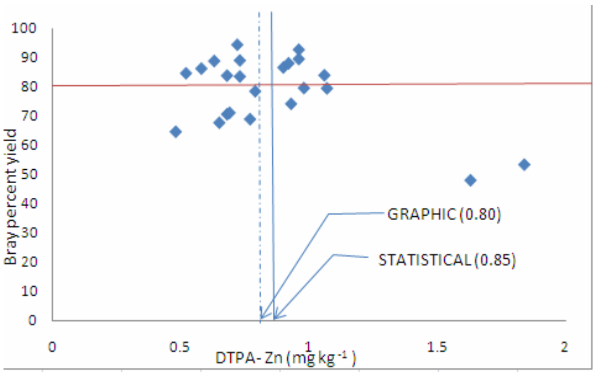
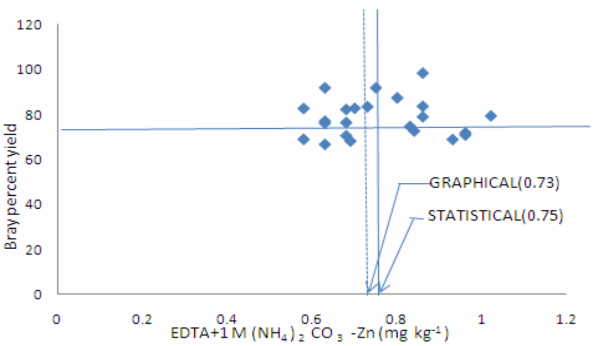
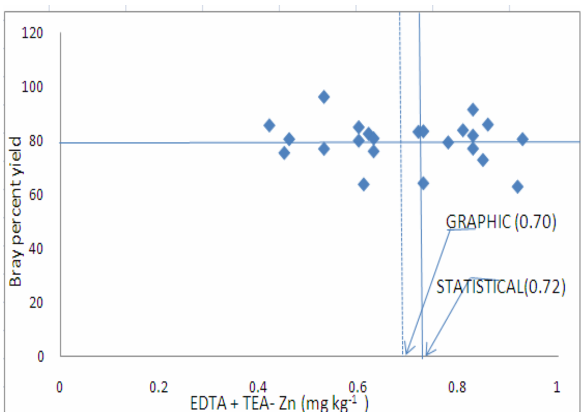


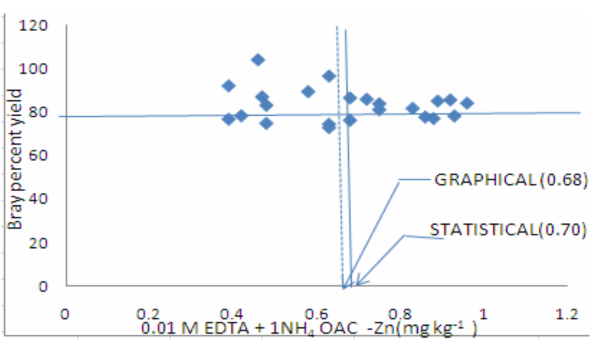
(a). DTPA



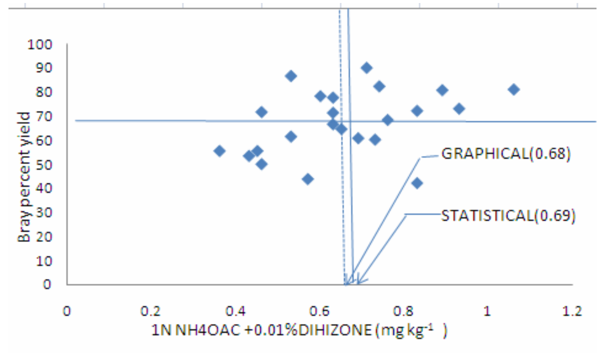
(b). EDTA+1 M $(NH_4)_2CO_3$



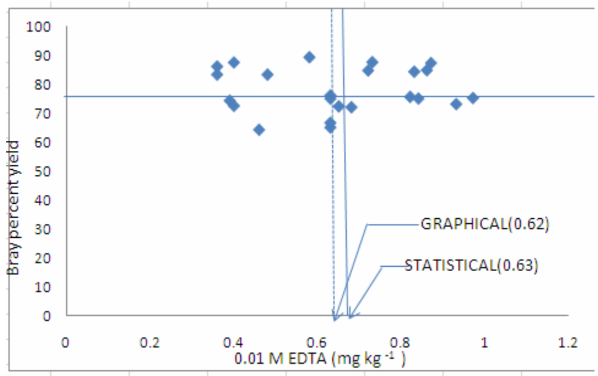
(c). 0.01 M EDTA + TEA



(d). 0.01 M EDTA + $1NH_4OAC$



(e). 1N NH_4OAC +0.01%DIHIZONE



(f). 0.01 M EDTA

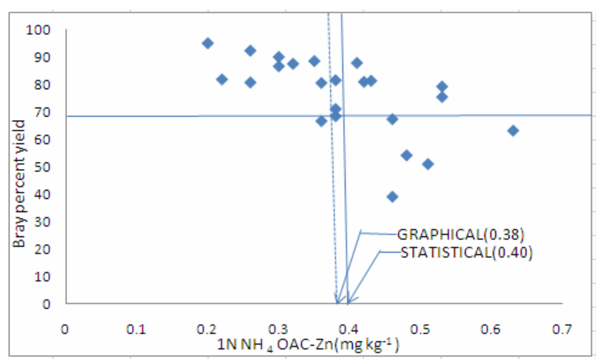


Figure-1. Critical limit of Zn in vertisol among various extractants.

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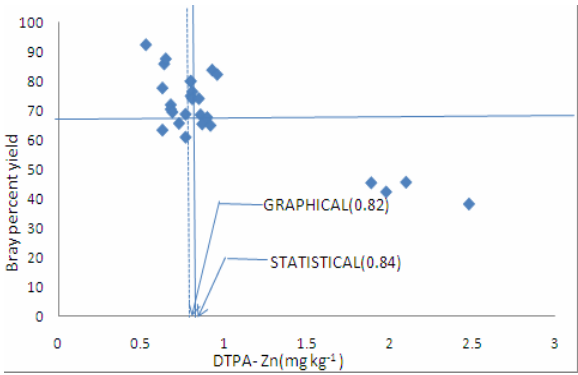
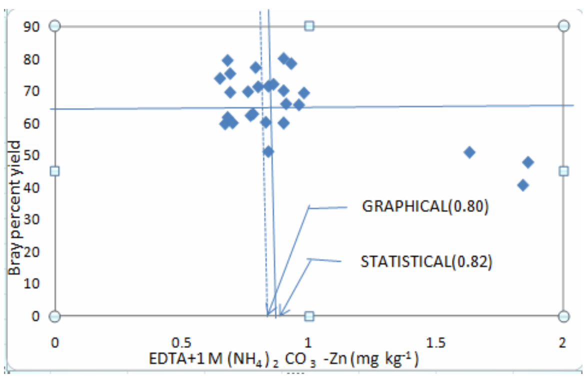
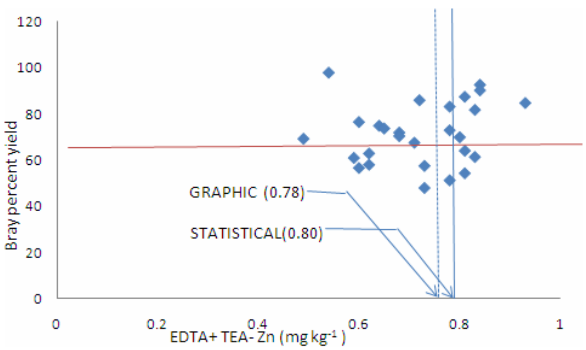


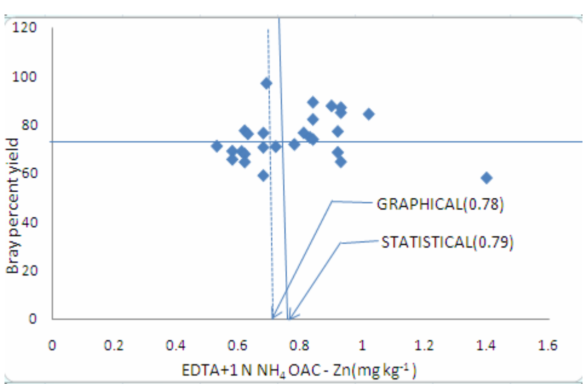
(a). DTPA- Zn



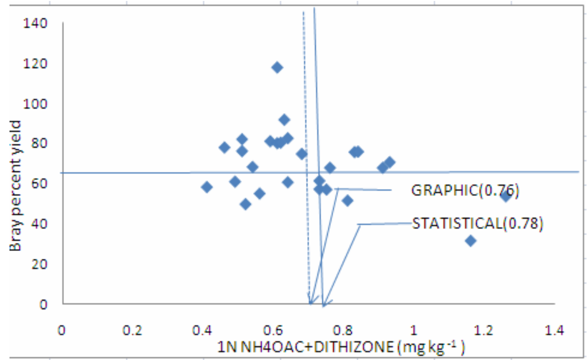
(b). 0.01 M EDTA + 1 M $(NH_4)_2CO_3$



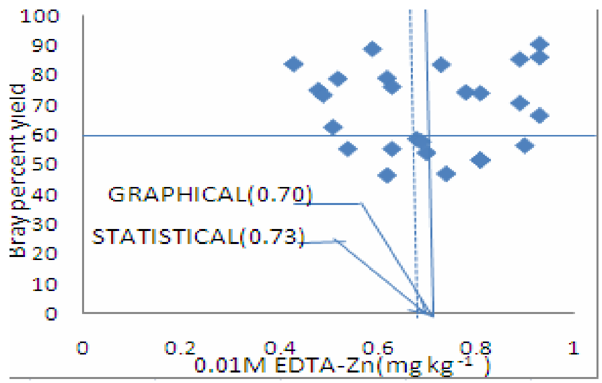
(c). 0.01 M EDTA + TEA-



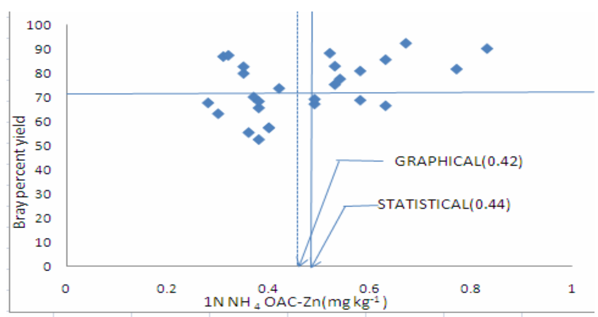
(d). 0.01 M EDTA+1 N NH_4OAC



(e). 1 N NH_4OAC + 0.01% DITHIZONE



(f). 0.01 M EDTA



(g). 1 N NH_4OAC

Figure-2. Critical limit of Zn in entisol among various extractants.

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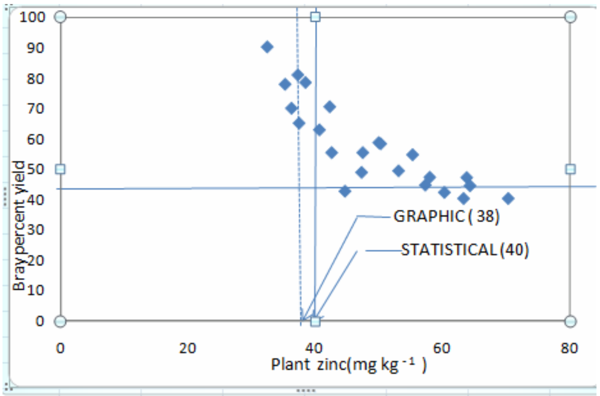
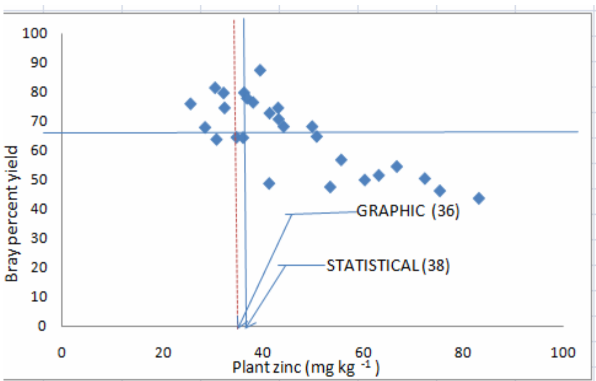


(a)



(b)

Figure-3. Critical limits of plant Zn (a) Vertisol (b) Entisol.

CONCLUSIONS

The study thus indicates that DTPA is a better extractant for assessing available zinc status for Veeranam command area. It is expected that rice crop will respond to Zn application when the soils contain less than 0.85 ppm (Vertisol) and 0.84 (Entisol) DTPA extractable Zn and rice plant with Zn concentration less than 40 and 38 ppm. Based on the critical limit, 66% soils were deficient in zinc in Vertisol and 69% in Entisol.

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