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Distribution of zinc fractions in paddy fields of Manipur

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Abstract

An experiment to study the distribution of zinc in some valley soils of Manipur was conducted during *rabi* season of 2016-17. Twenty soil samples were collected from different paddy fields of Manipur. All the soil samples were acidic in nature with mean value of pH 5.52. The mean electrical conductivity was 0.09 dSm^{-1}. There was wide variation of organic carbon content with a mean value of 10.82 g kg^{-1}. The mean cation exchange capacity, available nitrogen, available phosphorus and available potassium were 18.0 [Cmol $(p^{+})kg^{-1}$], 303.98 kg ha^{-1}, 28.68 kg ha^{-1} and 231.06 kg ha^{-1}, respectively. The studied soils were clay in texture. The mean value of available (DTPA extractable) zinc was 0.91 mg kg^{-1}. The DTPA extractable zinc show positive and significant correlation with EC, OC, CEC, available nitrogen, available potassium, silt and clay. A negative and significant correlation was observed with pH, available phosphorus and sand. Sequential extraction scheme was used to fractionate zinc into water soluble + exchangeable (WSEX), organically complexed (OC), amorphous sesquioxide bound (AMOX), crystalline sesquioxide bound (CRYOX), manganese oxide bound (MnOX) and residual zinc (Res-Zn). The distribution of zinc in the soil on the basis of average concentration was in the order: WSEX-Zn (0.40 mg kg^{-1}) < CRYOX-Zn (1.35 mg kg^{-1}) <MnOX-Zn (1.97 mgkg^{-1}) < AMOX-Zn (3.10 mg kg^{-1}) < OC-Zn (3.22 mg kg^{-1}) < Res-Zn (85.90 mg kg^{-1}). All the zinc fractions showed positive correlation with EC, OC, CEC, available nitrogen, available potassium, clay and negative correlation with pH, available phosphorus and silt.

Keywords: zinc, fractions, paddy, DTPA, organic carbon and soil pH

Introduction

Zinc plays an important role in several plant metabolic processes; it activates enzymes and is involved in protein synthesis and carbohydrate, nucleic acid and lipid metabolism (Marschner, 1986; Pahlsson, 1989) [12, 15]. However, like other heavy metals when Zn is accumulated in excess in plant tissues, it causes alteration in vital growth processes such as photosynthesis and chlorophyll biosynthesis (Doncheva *et al.*, 2001) [5] and membrane integrity (De Vos *et al.*, 1991) [4]. An excess of Zn has been reported to have a negative effect on mineral nutrition (Chaoui *et al.*, 1997) [3]. Zinc is one of the important micronutrients essential for plants, animals and human health. It is needed in very small amount but from the nutritional point of view, it is indispensable like any other essential nutrients. Almost half of the soils in the world are deficient in zinc. Indian soils are generally low in zinc. The deficiency is even more severe (60%) in acidic soils of North-Eastern India (Kumar *et al.*, 2016) [6], which might be one of the reasons behind lower crop productivity in the region. Adequate zinc fertilization is therefore, crucial to exploit the yield potential of crops. In order to increase productivity, correction of Zn deficiency is therefore, necessary which in turn requires the precise evaluation of available zinc in soil.

The different soil zinc pools are distinguished as water soluble, exchangeable, adsorbed, chelated or complexed zinc. The distribution of different Zn forms in soil depends on the chemical and physical properties of the soil. The readily available zinc forms *viz.*, water soluble, exchangeable and chelated zinc forms are in reversible equilibrium with each other (Viets, 1962) [17].

Water soluble plus exchangeable and organically complexed forms are considered to be available, amorphous sesquioxide bound form is potentially available, while crystalline sesquioxide bound and residual Zn forms are unavailable to plants (Mandal *et al.*, 1992) [10]. Considering the above facts the following objectives were undertaken viz. distribution and correlation of different forms of zinc with some physico-chemical properties of the soils.

Materials and Methods

Surface soil samples (0-15cm) of twenty soil samples were collected from different paddy fields of Manipur. The soil samples were processed and analyzed for pH (Jackson, 1973), available nitrogen using alkaline permanganate method (Subbiah and Asija, 1956) [16], available phosphorus using 0.03 (N) NH_4F in 0.025 N HCl (Page *et al.* 1982) [14], K extraction in 1 N neutral NH_4OAc (Lanyon and Heald, 1982) [7], soil organic matter (Walkley-Black, 1934). Cation Exchange Capacity (CEC) was determined in neutral 1 N NH_4OAc (Borah, 1987) [1]. Particle size distribution was determined by the hydrometer method (Bouyoucous, 1927) [2]. Soil available zinc was determined using Atomic Adsorption Spectrophotometer (ASS) as described by Lindsay and Norvell (1978) [9]. Different forms of zinc viz., water soluble plus exchangeable (WSEX), organically complexed (OCx), amorphous sesquioxide bound form (AMOX), crystalline sesquioxide bound form (CRYOX), and manganese oxide bound form (MnOX) were determined by sequential fractionation procedure outlined by Murthy (1982) [13] modified by Mandal and Mandal (1986) [11].

Statistical analysis

The data obtained was analyzed using the SPSS Statistical Program (SPSS, 16) to obtain the means of Zn concentration in the different pools. In addition, correlation analysis was done to obtain the relationship between Zn concentrations in the various pools and soil properties.

Results

Some physico-chemical properties of the soils

The studied soil samples were acidic in nature. The pH values ranged from 5.02 to 6.51 with a mean of5.52 (Table 1). The electrical conductivity of soil varies from 0.05 dSm^{-1} to 0.15 dSm^{-1} at 25°C.The mean value of electrical conductivity was 0.09 dSm^{-1} at 25°C. (Table 1)

The organic carbon content in the soil samples was high with a mean value of 10.82 g kg^{-1}. The organic carbon content in the soils ranged from 5.70 to 20.30 g kg^{-1}. The wide variation of carbon content may be due to various locations, altitude as well as climatic zones of the state. (Table 1)

The nitrogen content of the soil samples collected from different locations were 146.35 kg ha^{-1} to 405.59 kg ha^{-1} i.e. low to medium available nitrogen on the study soils. The average of available nitrogen in these soils series was 303.98 kg ha^{-1}.The variation of available nitrogen content in the soil may be due to different amount of organic carbon present in soils which released variable amount of inorganic nitrogen in the soil. (Table 1)

The available phosphorus content in these soil series ranged from 21.57 kg ha^{-1} to 43.42 kg ha^{-1}. The mean value of the available phosphorus of the studied soil samples was 28.68 kg ha^{-1}. (Table 1)

The available potassium content in these soil series ranged from 163.89 kg ha^{-1} to 298.41 kg ha^{-1}. The mean value of the available potassium of the studied soil samples was 231.06 kg ha^{-1}. (Table 1)

The cation exchange capacity content of the soils was between 11.9 [cmol(p+) kg^{-1}] and 31.5 [cmol(p+) kg^{-1}]. The mean value of the cation exchange capacity of the studied soil samples was 18.0 [cmol(p+) kg^{-1}].

The clay content of the soil varied from 42.0 per cent to 76.1 per cent. The silt and sand contents of the soils ranged from 10.0 per cent to 35.0 per cent and 8.0 per cent to 30.5 per cent, respectively. All the studied soil samples in the area were clay in the textural class (Table 1).

Table 1: Some physico-chemical properties of soil

Soil Samples	pH (mol/lit)	EC (dSm-1)	Org. C (g kg-1)	Av. N (kg ha')	Av. P (kg ha-')	Av. K (kg ha-1)	CEC [cmol(Plkg-1	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	6.	0.07	9.60	318.	32.	228.	19.30	22.10	32.50	45.40	Clay
2	5.70	0.07	16.80	293.	38.	187.	13.30	22.10	27.50	50.40	Clay
3	5.	0.08	9.90	380.50	29.	240.	16.00	11.20	22.50	66.30	Clay
4	7.	0.05	5.70	146.	43.	164.	11.90	16.20	30.00	53.80	Clay
5	5.	0.10	7.50	246.70	28.	238.	14.70	10.50	30.00	59.50	Clay
6	6.	0.06	6.30	401.	27.	169.90	16.00	8.00	32.50	59.50	Clay
7	6.	0.08	6.40	176.	27.	201.	20.10	18.70	20.00	61.30	Clay
8	5.	0.10	8.40	339.	26.	291.20	19.10	11.40	12.50	76.10	Clay
9	5.	0.09	7.20	171.	27.	185.	13.90	22.80	17.50	59.70	Clay
10	5.	0.13	20.00	401.	27.	298.	16.50	8.90	30.00	61.10	Clay
11	5.	0.12	16.80	255.	26.00	286.	27.90	8.90	20.00	71.10	Clay
12	6.	0.10	5.80	364.	39.	188.	12.10	30.50	27.50	42.00	Clay
13	6.	0.09	11.00	360.	30.	198.	16.70	26.90	10.00	63.10	Clay
14	5.	0.05	10.40	397.	26.	165.	14.70	25.30	17.50	57.20	Clay
15	5.	0.08	16.80	272.	25.	205.	22.70	25.50	25.00	49.50	Clay
16	5.	0.09	9.60	335.	24.	243.	14.30	14.80	32.50	52.70	Clay
17	6.	0.09	9.20	284.	26.	279.	19.50	9.80	32.50	57.70	Clay
18	5.	0.07	10.60	351.	25.	270.	14.80	17.30	35.00	47.70	Clay
19	5.	0.08	8.10	184.	26.	290.	25.70	22.80	20.00	57.20	Clay
20	5.	0.15	20.30	406.	22.	298.	31.50	9.80	20.00	70.20	Clay
Mean	6.	0.09	11.	304.	29.	231.	18.00	17.20	24.80	58.10	

Distribution of Zinc

The amount of zinc in each of the chemical pools or forms differs due to the range of zinc concentrations found in the soil parent material and the extent of weathering. $Zn^{2+}$is released from many primary minerals into the soil solution during rock weathering. The total zinc concentration of soils is related to the composition of the parent rock material and soil mineralogy. In soil, zinc forms complexes with organic acids, humic substances and other types of dissolved organic carbon. The total zinc concentration is not used for evaluating the availability of soil zinc to the plants because only a small amount of total zinc is exchangeable or soluble. The availability of zinc to plants depend on several soil factors such as the concentration of Zn in solution, ion speciation and the interaction of Zn with other macronutrients and micronutrients (Li *et al.*, 2003) [8]. Response to applied zinc differs among pulses because of wide differences in the sensitivity of the crops to zinc. When the supply of zinc to plants is inadequate (i.e. there is deficiency of zinc), one or more of many important physiological functions that depend on zinc are impaired, and plant growth is adversely affected. Therefore, understanding and knowledge of zinc deficiency would facilitate the appropriate management of this problem.

Available (DTPA-extractable) zinc

The available Zn in soil varied from 0.57 mg kg^{-1} to 1.68 mg kg^{-1}. The mean value of the available Zn of the studied soil was 0.91 mg kg^{-1} (Table 2).

The DTPA extractable zinc (Table 3) show positive and significant correlation with EC (r=0.633**), OC (r=0.591**), CEC (r=0.561**), available nitrogen (r=0.551*), available potassium (r=0.560*), silt (r=0.068) and clay (r=0.462*). A negative and significant correlation was observed with pH (r=-0.599**), available phosphorus (r=-0.523*) and sand (r=-0.637**).

Zinc fractions

Water soluble + exchangeable zinc (WSEX-Zn)

WSEX-Zn fraction ranged from 0.11 to 1.14 mg kg^{-1} and the mean value was 0.40 mg kg^{-1}. (Table 2).

WSEX-Zn fraction (Table 3) was positively and significantly correlated with EC (r=0.542*), organic carbon (r=0.67 **), CEC (r=668**), available nitrogen (r=0.457*) but non-significant with available potassium (r=0.397) and Clay (r=0.214). It was negatively and significantly correlated with pH (r=-0.496*, Fig. 2a.) but non-significant with available phosphorus (r=-0.341), sand (r=-0.137) and silt (r=-0.123).

Organically complexed zinc (OCx-Zn)

OCx-Zn fraction ranged from 2.36 to 4.44 mg kg^{-1} and the mean value was 3.22 mg kg^{-1}. (Table 2). OCx-Zn fraction (Table 3) was positively and significantly correlated with EC (r=0.638**), organic carbon (r=0.548*), CEC (r=0.498*), available potassium (r=0.675**), clay (r=0.516*) but non-significant with available nitrogen (r=0.259). It was negatively and significantly correlated with pH (r=-0.554 *), available phosphorus (r=-0.643**) but non-significant with sand (r=-0.113) and silt (r=-0.018).

Amorphous sesquioxide bound zinc (AMOX-Zn)

AMOX-Zn fraction ranged from 1.88 to 4.64 mg kg^{-1} and the mean value was 3.10 mg kg^{-1}. (Table 2). AMOX-Zn fraction (Table 3) was positively and significantly correlated with EC (r=0.677**), organic carbon (r=0.447*), CEC (r=0.460*), available potassium (r=0.482*), but non-significant with available nitrogen (r=0.295) and clay (r=0.376). It was negatively and significantly correlated with pH (r=-0.555*), available phosphorus (r=-0.633**) but non-significant with sand (r=-0.021) and silt (r=-0.138).

Crystalline sesquioxide bound zinc (CRYOX-Zn)

CRYOX-Zn fraction ranged from 0.46 to 2.21 mg kg^{-1} and the mean value was 1.35 mg kg-1. (Table 2).CRYOX-Zn fraction (Table 3) was positively and significantly correlated with EC (r=0.555*), organic carbon (r=0.501*), available nitrogen (r=0.517*), but non-significant with CEC (r=0.248), available potassium (r=0.323) and clay (r=0.404). It was negatively and non-significantly correlated with pH (r=-0.334), available phosphorus (r=-0.300), sand (r=-0.322) and silt (r=-0.382).

Manganese oxide bound zinc (MnOX-Zn)

MnOX-Zn fraction ranged from 0.65 to 3.23 mg kg^{-1} and the mean value was 1.97 mg kg^{-1}. (Table 2).MnOX-Zn fraction (Table 3) was positively and non-significantly correlated with EC (r=0.433), organic carbon (r=0.432), CEC (r=0.261), available nitrogen (r=0.208) and available potassium (r=0.177). It was negatively and significantly correlated with pH (r=-0.464*), but non-significant with available phosphorus (r=-0.225), sand (r=-0.038) and silt (r=-0.315) and clay (r=-0.022).

Residual zinc (Res-Zn)

Res-Zn fraction ranged from 65.88 to 115.67 mg kg^{-1} and the mean value was 85.90 mg kg^{-1}. (Table 2).Res-Zn fraction (Table 3) was positively and significantly correlated with EC (r=0.614**), organic carbon (r=0.678**) but non-significant with CEC (r=0.424), available nitrogen (r=0.143), available potassium (r=0.224) and clay (r=0.382). It was negatively and significantly correlated with pH (r=-0.453*), but non-significant with available phosphorus (r=-0.266), sand (r=-0.399) and silt (r=-0.492).

Total zinc (Total-Zn)

Total-Zn fraction ranged from 71.33 to 131.33 mg kg^{-1} and the mean value was 95.93 mg kg^{-1} (Table 2). Total-Zn fraction (Table 3) was positively and significantly correlated with EC (r=0.658**), organic carbon (r=0.702**), CEC (r=0.455*), but non-significant with available nitrogen (r=0.187), available potassium (r=0.278) and clay (r=0.396). It was negatively and significantly correlated with pH (r=-0.499*), but non-significant with available phosphorus (r=-0.322), sand (r=-0.373) and silt (r=-0.484).

Conclusion

The distribution of zinc in the soil on the basis of average concentration was in the order: WSEX-Zn (0.40 mg kg^{-1}) < CRYOX-Zn (1.35 mg kg^{-1}) <MnOX-Zn (1.97 mgkg^{-1}) < AMOX-Zn (3.10 mg kg^{-1}) <OCx-Zn (3.22 mg kg^{-1}) < Res-Zn (85.90 mg kg^{-1}). All the zinc fractions showed positive correlation with EC, OC, CEC, available nitrogen, available potassium, clay and negative correlation with pH, available phosphorus and silt.

Table 2: Distribution of different zinc fractions (mg kg-1) in soils

Soil Samples	DTPA extractant	Zinc fractions						
	Available Zn	WSEX-Zn	OCx-Zn	AMOX-Zn	CRYOX-Zn	MnOX-Zn	Res-Zn	Total-Zn
1	1.06	0.68	2.84	2.40	1.33	2.65	74.76	84.67
2	0.66	0.36	2.67	1.95	1.53	2.38	102.44	111.33
3	1.08	0.33	3.16	2.53	1.33	1.70	72.28	81.33
4	0.57	0.11	2.36	1.88	0.46	0.65	65.88	71.33
5	0.75	0.37	2.63	4.61	1.55	2.80	87.37	99.33
6	1.14	0.40	2.83	3.35	0.79	2.26	85.71	95.33
7	0.86	0.31	3.31	2.48	1.78	0.72	81.40	90.00
8	0.83	0.29	3.65	3.13	1.81	0.85	83.60	93.33

9	0.63	0.13	3.68	3.08	0.81	2.65	101.65	112.00
10	1.38	0.64	4.24	3.83	1.90	3.02	105.71	119.33
11	1.17	0.41	3.92	3.79	127	1.72	94.89	106.00
12	0.59	0.28	2.43	216	127	1.80	76.79	85.33
13	0.85	0.49	2.71	3.01	1.87	2.05	99.86	110.00
14	0.76	0.39	3.12	2.77	1.59	1.60	76.52	86.00
15	0.72	0.51	2.93	316	1.13	2.13	89.53	100.00
16	1.09	0.16	2.96	3.19	1.23	2.40	70.73	80.67
17	0.91	0.23	3.76	2.91	1.44	1.22	69.78	79.33
18	0.83	0.32	3.97	327	1.10	0.77	76.57	86.00
19	0.71	0.45	2.75	2.68	0.52	2.83	86.77	96.00
20	1.68	1.14	4.44	4.64	221	3 23	115.67	131.33
Mean	0.91	0.40	3.22	3.10	1.35	1.97	85.90	95.93

(WSEX-Zn = Watersoluble+Exchanaeable zinc: OCx-Zn = organically comolexed zinc: AMOX-Zn = Amorphous sesouioxi de bound zinc; CRYOX-Zn = Crystalline sesquioxide bound zinc; MnOX-Zn = Manganese oxide bound zinc; Res-Zn = Residual zinc; Total-Zn = Total zinc).

Table 3: Simple correlation coefficient of different forms of zinc and soil physico-chemical properties

	Soil properties	**DTPA extractant**	**Zinc fractions**						
		Available Zn	**WSEX-Zn**	**OCx-Zn**	**AMOX-Zn**	**CRYOX-Zn**	**MnOX-Zn**	**Res-Zn**	**Total Zn**
1	pH	-0.599"	-0.496'	-0.554'	-0.555'	-0334	-0.464'	-0.453'	-0.499'
2	EC	0.633 "	0.542*	0.638 "	0.677 "	0.555"	0.433	0.614 "	0.658 "
3	OC	0.591 "	0.673 "	0.548 *	0.447 *	0.501*	0.432	0.678 "	0.702 "
4	CEC	0.561 **	0.668 **	0.498 *	0.460 *	0.248	0.261	0.424	0.455 *
5	Av. **N**	0.551 *	0.457'	0.259	0.295	0.517*	0.208	0.143	0.187
6	Av. P	-0.523 *	-0.341	-0.643"	-0.633'*	-0.300	-0.225	-0.266	-0.322
7	Av. K	0.560 *	0.397	0.675 "	0.482 *	0.323	0.177	0.224	0.278
8	Sand	-0.637 "	-0.137	-0.113	-0.021	-0.322	-0.038	-0.399	-0.373
9	Silt	0.068	-0.123	-0.018	-0.138	-0.382	-0.315	-0.492	-0.484
10	Clay	0.462 *	0.214	0.516'	0.376	0.404	-0.022	0.382	0.396

* Sontficant at 5 percent cen ** significant at 1 percent level

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