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Dynamics of Zinc in Sodic Soil with Zinc Enriched Organics

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A B S T R A C T

An incubation experiment was conducted at ADAC & RI, Trichy, to study the effect of $ZnSO_4$, chelated Zn and Zn enriched organics on dynamics of Zn in sodic soil at different incubation period. The organics viz., FYM, press mud, poultry manure and vermicompost were enriched (10:1 ratio) with $ZnSO_4$ @ 37.5 kg ha^{-1} (recommended dose for hybrid maize). The $ZnSO_4$, chelated Zn and Zn enriched organics were added @ 37.5 kg $ZnSO_4$ ha^{-1}. Incubated soil sample were analysed for Zn fractions viz., water soluble + exchangeable Zn (WSEX-Zn), organically bound Zn (OM-Zn), Mn-oxides bound Zn (MNOX-Zn), Zn bound by amorphous sesquioxides (AFeOX-Zn), Zn bound by crystalline sesquioxides (CFeOX-Zn), DTPA Zn and total at different intervals (15, 30 and 45 DAI). Among the various treatments, Zn enriched organics and chelated Zn applied treatments recorded higher water soluble + exchangeable Zn, DTPA-Zn and organically bound Zn when compared to application of $ZnSO_4$ alone. The distribution of different fraction of Zn in soil were significantly influenced by Zn enriched organics and $ZnSO_4$ application and found the in order of WSEX-Zn < AFeOX-Zn < OM-Zn < CFeOX-Zn < MNOX-Zn < RES-Zn fractions. The higher amount Zn release was observed at Zn enriched organics and commercially chelated Zn application than the application of $ZnSO_4$ alone and control. The release of WSEX, OM, CFeOX attained peak at 15 DAI and declined thereafter upto 45 DAI whereas the MNOX, AFeOX, RES and TOTAL-Zn fraction increases till the end of the experiment. The experiment received that the Zn fraction which contributes to available Zn considerably increased under Zn enriched organics in sodic soil.

Introduction

Currently more than 20 per cent of the world's irrigated land is salt affected. Of that about 60 per cent are sodic soils, warranting attention for efficient, inexpensive and environmentally feasible amelioration. But very poor farmers are unable to reclaim the soil and use the extra dose of fertilizer for increasing the availability of nutrients. The transformation and availability of several plant nutrient elements are affected by soil sodicity. Micronutrients such as zinc (Zn), iron (Fe), manganese (Mn) and copper (Cu) also exhibit low levels of solubility in sodic soils, which results in micronutrient deficiencies. Use of Zn enriched organics is one of the options for unreclaimed sodic soil to make these nutrients available to plants. Information on soil zinc fraction is essential

for understanding its chemical reactions and bioavailability. Hence the present investigation was aimed to study the influence of different Zn enriched organics on release pattern of different Zn fraction in sodic soils.

Materials and Methods

An incubation experiment was conducted at Anbil Dharmalingam Agricultural College & Research Institute (ADAC&RI), Trichy to study the availability of different forms of soil Zn due to application of $ZnSO_4$, chelated Zn and Zn enriched organics. The experimental soil was clay loam and black in colour (wet soil) belonging to Panjappur series of fine mixed, calcareous isohyperthermic vertic *ustropept*.

The soil was alkaline in reaction with pH 8.90 and non saline (0.19 dS m^{-1}). The ESP of soil was 26.85 percentage. The organic carbon content was low (0.39 per cent). The available N ($KMnO_4$ -N) was low (216 kg ha^{-1}) while the available P (Olsens-P) was medium (15.5 kg ha^{-1}). The available K (NH_4oAC-K) status was found to be 265 kg ha^{-1} (medium). The exchangeable Ca, Mg, Na and K content was 10.1, 8.21, 6.21 and 1.20 cmol (p^+) kg^{-1} respectively. With regards to the available micronutrient status of the soil, DTPA-Mn was high (9.3 mg kg^{-1}) compared to Fe (2.5 mg kg^{-1}), Zn (0.45 mg kg^{-1}) and Cu (1.00 mg kg^{-1}). The biological properties of the initial soil showed that bacteria, fungi and actinomycetes were 11.3 x 10^5, 3.00 x 10^2 and 0.95 x 10^3 CFU g^{-1} respectively (Table 1).

The organics viz., Farm yard manure (FYM), press mud (SPM), poultry manure (PM) and vermicompost (VC) were mixed with $ZnSO_4$ at 10:1 ratio. The enriched organics were incubated for 45 days and moisture content was maintained @ 60 %. The $ZnSO_4$ enriched organics were applied @ 37.5 kg $ZnSO_4$ ha^{-1}. The treatments includes,

T_1 - Control.
T_2 - 37.5 kg $ZnSO_4$ ha^{-1}
T_3 - commercially chelated zinc equivalent to 37.5 kg $ZnSO_4$ ha^{-1}
T_4 - 37.5 kg ha^{-1} $ZnSO_4$ enriched FYM
T_5 - 37.5 kg ha^{-1} $ZnSO_4$ enriched SPM
T_6 - 37.5 kg ha^{-1} $ZnSO_4$ enriched PM
T_7 - 37.5 kg ha^{-1} $ZnSO_4$ enriched VC

500 g of air dried soil was weighed and transferred to plastic containers. The $ZnSO_4$ enriched organic manure *viz.*, FYM, press mud, poultry manure and vermicompost were applied @ 37.5 kg ha^{-1} $ZnSO_4$ to the treatment viz., T_4, T_5, T_6 and T_7 respectively. For T_2 treatment, $ZnSO_4$ alone was applied @ 37.5kg ha^{-1}. For T_3 treatment, chelated Zn equivalent to 37.5 kg ha^{-1} of $ZnSO_4$ was applied. A control (T_1) was maintained without $ZnSO_4$. Required quantity of distilled water was added to achieve a final moisture content equivalent to 60 % of field capacity. Based on the weight loss, distilled water was added to the container to maintain the moisture content throughout the incubation experiment. The Zn fractions viz., water soluble + exchangeable Zn (WSEX-Zn), organically bound Zn (OM-Zn), Mn- oxides bound Zn (MnOX-Zn), Zn bound by amorphous sesquioxides (AFeOX-Zn), Zn bound by crystalline sesquioxides (CFeOX-Zn), available Zn (DTPA-Zn) and total Zn were analyzed at different intervals (15, 30 and 45 DAI) as per the standard procedure. Moisture content was assessed and the results were expressed on oven dry basis.

Methods zinc fraction analysis

Soil Zn fractions were estimated by using different extractants of volume 50 ml each. First 5g soil was treated with 50 ml of 1 N ammonium acetate followed by 50 ml of 0.05 M cupric acetate, 50 ml of 0.1 M Hydroxylamine hydrochloride, 50 ml 0.2 M Acidified ammonium oxalate and 0.1 M Ascorbic acid in the acidified ammonium

oxalate to obtain Water soluble + Exchangeable Zn, Organically Bound Zn, Mn – oxides Bound Zn, Zn bound by amorphous sesquioxides and Zn bound by crystalline sesquioxides fraction respectively.

Different fraction of Zn were sequentially extracted by the above extracting solutions and determined with the help of atomic absorption spectrophotometer. Residual Zn fraction was calculated taking differences between total and sum of the other Zn fractions.

Results and Discussion

Water soluble + exchangeable Zn

At 15 DAI the higher value of WSEX-Zn recorded in the treatments which received chelated Zn (0.76 mg kg^{-1}) and Zn enriched organics (0.69 to 0.75 mg kg^{-1}) than the application of $ZnSO_4$ alone (0.48 mg kg^{-1}). Though WSEX-Zn increased at 15 DAI in $ZnSO_4$ alone applied treatments, it is drastically reduced to the initial level with the advancement of incubation period (Table 2). Since the soil is alkaline in nature the WSEX-Zn might have been precipitated as Zn hydroxide and carbonate (residual Zn). However in chelated Zn and Zn enriched organics, the WSEX-Zn level increased at 15 DAI and almost maintained throughout the incubation period. It may be attributed to the retention of Zn on organic complex and it is in conformity to the early reports (Kumar and Basavaraj, 2008).

In the present study, the concentration and per cent contribution of WSEX-Zn fraction to total Zn was the lowest among the entire Zn fraction. The high buffering capacity of these soil resulted in low amount of water soluble + exchangeable zinc. Similar findings were reported by Veeranagappa *et al.,* (2011).

Organically bound Zn

The OM-Zn showed higher value (2.50 to 2.58 mg kg^{-1}) in Zn enriched organics compared to the $ZnSO_4$ (1.58 mg kg^{-1}) and chelated Zn (2.18 mg kg^{-1}) applied treatments (Table 2) at 15 DAI and decreased with incubation period. Similar to WSEX-Zn, this fraction also contributed very less to total zinc and this could be due to medium organic matter content of the experiment soil. The per cent contribution of OM-Zn was only 0.48 % from the total Zn. Similar results were reported by Preetha and Stalin (2014) and they stated that lower content of organically bound Zn was due to low organic carbon status of the soil. The OM-Zn in soil decreased with time which may be due to sorption.

Manganese oxide bound Zn

The per cent contribution of MNOX-Zn from total Zn was 1.5 per cent and release of this fraction showed highest value (3.20 to 3.82 mg kg^{-1}) at 45 DAI in all the treatments (Table 2). This can be attributed to higher amount of Zn adsorption on the surface of the oxides as the soil might be having relatively higher manganese content. Similar finding were reported by Preetha and Stalin (2014).

Amorphous sesquioxide bound Zn

AMOX fraction of Zn was increased with application of $ZnSO_4$ (2.13 mg kg^{-1}), chelated Zn (2.19 mg kg^{-1}) and organic enriched treatments (2.23 to 2.29 mg kg^{-1}) at 15 DAI (Table 2). As the incubation periods increases AMOX-Zn was decreases in all the treatments. Zn enriched organics applied treatments maintain the AMOX-Zn availability which may be attributed to the enhanced release of Zn present in mineral fractions as a result of action of decomposition products of added organic

matter and enhanced microbial activity under these conditions (Dutta *et al.*, 1989).

Crystalline sesquioxide bound Zn

The contribution of this fraction from total Zn was 1.05 per cent. This fraction was dominant when compared to WSEX-Zn and OM-Zn fractions, which might be due to predominance of crystalline iron oxide content in soil (Table 3). The CFeOX-Zn shows higher rate of release at 15 DAI compare to the 45 DAI with application of $ZnSO_4$ (2.60 mg kg^{-1}), chelated Zn (2.67 mg kg^{-1}) and Zn enriched organic manures (2.74 to 2.89 mg kg^{-1}). This fraction is more stable particularly in upland condition of soil, as reported by Manoj kumar Sharma *et al.*, (2014). Apart from reversible adsorption by cation exchange, zinc can also be sorbed irreversibly by lattice penetration in clay minerals. The latter mechanism fixes the zinc in excess of the cation exchange capacity and may be due to sorption of zinc in a hydrolysed form and precipitation of $Zn(OH)_2$. This 'fixation' of zinc tends to increase over time and can affect the long-term availability of zinc fertilizers (McBride, 1994).

DTPA-Zn

Available zinc is the important fraction which will be readily available after application of Zn fertilizer in the soil. The $ZnSO_4$, chelated Zn and Zn enriched organics significantly increased the available Zn immediately after application at 15 DAI, thereafter decreased at 45 DAI (Table 3). Increase in amount of available zinc fractions at 15 DAI might be due to the higher solubility and mobility of the added zinc source.Low levels of bio-available Zn in control has been attributed to one or a combination of low native Zn, very slow solubility of Zn from soil minerals and strong adsorption of Zn on soil surfaces (Rieuwerts *et al*., 2006).

There was a significant build-up in the available Zn observed in the Zn enriched organics applied plot.

The available Zn content status increased to the tune of 0.54 mg kg^{-1} over control in Zn enriched organics. $ZnSO_4$ and chelated Zn applied treatments released the available Zn immediately and converted to residual fraction compare to Zn enriched organics applied treatment. Zn enriched organics slowly release the available Zn and maintain the available pool longer time of incubation period (Kiekens, 1980).

Though uniform quantity of $ZnSO_4$ (37.5 kg ha^{-1}) was applied to all the treatments (control T_1), the increases in available Zn was low in $ZnSO_4$ alone applied treatment.

Takkar and Sindhu (1979) reported that Zn concentration in the soil solution was regulated by both $Zn(OH)_2$-Zn^{2+} and $ZnCO_3$-Zn^{2+} systems, during the initial periods and thereafter by $ZnCO_3$-Zn^{2+} system alone because of the buffering effect of the soil carbonate equilibrium. Similar findings were also observed by Mandal *et al.*, (1993) and concluded that precipitation of Zn as hydroxide, carbonate and sulphide and it's adsorption on the surface of hydrated oxides of iron were at least partly responsible for the decrease with time.

Residual zinc

The per cent contribution of this fraction from total Zn was observed higher than the other fractions with 95.7 % in all the treatments. It is considered as the primary form of the native Zn and associated with soil mineral fractions. The greater percentage of Zn in the residual fraction likely indicated its greater tendency to become unavailable in the soil. This is because the residual fraction represented metals that are largely embedded

in sedimentary matrix and may not be available for remobilization except under very drastic conditions.

Residual Zn was non significantly influenced by the Zn application at any forms (Table 3). There was an increase in the residual Zn content with time which could be due to conversion of some amount of labile Zn into non-labile forms. Similar trend was also reported by Mishra *et al.,* (2009).

Total zinc

Total Zn content of soil was non significantly increased due to the application of ZnSO4, chelated Zn and organics (Table 3). Total is the native soil Zn included the available and non available pool. Total Zn was controlled by many factors like type of minerals present in the soil, climatic condition, type of cropping and management practices. Similar results were observed by Hemanth kumar and Basavaraj (2008).

Table.1 Characteristics of experiment soil

S.No	Parameter	Values
1	pH	8.90
2	EC ($dSm^{-1)}$	0.19
3	Organic carbon (%)	0.39
4	ESP	26.8
5	Available Nitrogen (kg ha^{-1})	216
6	Available Phosphorus (kg ha^{-1})	15.5
7	Available Potassium (kg ha^{-1})	265
8	DTPA-Fe (mg kg^{-1})	0.45
9	DTPA-Cu (mg kg^{-1})	2.50
10	DTPA-Mn (mg kg^{-1})	1.00
11	DTPA-Zn (mg kg^{-1})	9.30
12	WSEX-Zn	0.36
13	OM-Zn	0.89
14	MnOX-Zn	3.18
15	AFeOX-Zn	1.91
16	CFeOX-Zn	2.51
17	RES-Zn	220
18	Total-Zn	229
19	Exchangeable calcium (cmol (p^{+}) kg^{-1})	10.1
20	Exchangeable magnesium (cmol (p^{+}) kg^{-1})	8.21
21	Exchangeable sodium (cmol (p^{+}) kg^{-1})	6.20
22	Exchangeable potassium (cmol (p^{+}) kg^{-1})	1.20
23	Bacteria($\times 10^{5}$ CFU g^{-1} soil)	11.3
24	Fungi ($\times 10^{5}$ CFU g^{-1} soil)	3.00
25	Actinomycetes ($\times 10^{3}$ CFU g^{-1} soil)	0.95

Table.2 Effect of Zn enriched organics on Zn fraction I

Treatments	WSEX-Zn (mg kg^{-1})			OM-Zn (mg kg^{-1})			MnOX-Zn (mg kg^{-1})			AFeOX-Zn (mg kg^{-1})		
	15 DAI	30 DAI	45 DAI	15 DAI	30 DAI	45 DAI	15 DAI	30 DAI	45 DAI	15 DAI	30 DAI	45 DAI
T_1	0.39	0.37	0.35	0.94	0.91	0.89	3.20	3.25	3.37	1.90	1.97	2.00
T_2	0.48	0.42	0.40	1.58	1.55	1.53	3.82	4.04	4.18	2.13	2.20	2.23
T_3	0.76	0.65	0.63	2.18	2.10	2.06	3.74	3.96	4.10	2.19	2.26	2.29
T_4	0.69	0.68	0.67	2.50	2.47	2.5	3.33	3.55	3.69	2.23	2.30	2.33
T_5	0.73	0.70	0.68	2.53	2.52	2.50	3.28	3.50	3.65	2.27	2.34	2.36
T_6	0.70	0.69	0.67	2.52	2.50	2.49	3.31	3.53	3.64	2.25	2.32	2.35
T_7	0.75	0.72	0.70	2.58	2.55	2.53	3.29	3.52	3.67	2.29	2.36	2.39
CD(P=0.05)	0.03	0.03	0.03	0.09	0.09	0.09	0.19	0.20	0.20	0.10	0.11	0.11

Table.3 Effect of Zn enriched organics on Zn fraction II

Treatments	CFeOX-Zn (mg kg^{-1})			DTPA-Zn (mg kg^{-1})			RES-Zn(mg kg^{-1})			Total Zn (mg kg^{-1})
	15 DAI	30 DAI	45 DAI	15 DAI	30 DAI	45 DAI	15 DAI	30 DAI	45 DAI	
T_1	2.54	2.48	2.46	0.56	0.53	0.49	218	217	217	229
T_2	2.60	2.54	2.52	0.98	0.80	0.65	220	220	220	232
T_3	2.67	2.61	2.59	1.06	0.99	0.90	219	220	219	232
T_4	2.74	2.68	2.66	1.05	1.04	1.01	221	220	220	233
T_5	2.86	2.75	2.73	1.08	1.05	1.04	220	220	220	233
T_6	2.76	2.70	2.68	1.06	1.04	1.03	221	219	219	232
T_7	2.89	2.80	2.78	1.10	1.07	1.06	219	219	219	232
CD(P=0.05)	0.14	0.16	0.13	0.04	0.04	0.04	11	9	13	11

Based on the results, it can be concluded that the transformation of Zn is largely controlled by organic matter, chelated Zn and $ZnSO_4$ application due to considerable changes in the chemical and electrochemical properties of soil and thereby influence the transformation of zinc. The Zn enriched organics significantly increased Zn fractions due to the retention of Zn on organic complex owing to organic acid produced by decomposition of organic matter.

Different fractions of soil Zn were in dynamic equilibrium with each other. Depletion of water soluble, exchangeable and complexed forms of Zn occurred with build-up organic, occluded and residual fractions of Zn. Depleted levels of readily available Zn in soil could be replenished by the other pools of soil Zn. Understanding the distribution of zinc (Zn) fractions in soils is important for effective management of the fertilizer resources given world-wide, limitations of crop production and food quality by insufficient Zn.

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