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See end of the paper for authors' affiliations

Correspondence to :

P. VEERANAGAPPA
Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, G.K.V.K., BENGALURU (KARNATAKA) INDIA
Email : veera346@gmail.com

Impact of zinc enriched compost on availability of zinc and zinc fractions, nutrients uptake and yield of rice (*Oryza sativa* L.)

P. VEERANAGAPPA, H.C. PRAKASHA, VIJAY MAHANTHESH, K.R. ASHOKA, M.B. MAHENDRA KUMAR AND R. NAGARAJ

ABSTRACT

A field investigation was undertaken during *Kharif* 2008 at College of Agriculture, Shivamogga to study the impact of zinc enriched compost on availability of zinc and zinc fractions, nutrients uptake and yield of rice (*Oryza sativa* L.). The study revealed that uptake of nutrients by grain and straw was significantly higher in treatment package of practices followed by NPK + Zn-E compost at 15 kg ha^{-1} and NPK + Zn-E compost at 10 kg ha^{-1} treatments. Correlation studies revealed that the zinc fractions and soil chemicals properties showed positive relationship among each other. Soil chemical properties *viz.*, pH, EC, OC, available N, P, K, exchangeable Ca, Mg, available S, DTPA Zn, Cu, Mn and Fe were positively and significantly correlated with the zinc fractions. Uptake of nutrients (N, P, K, Ca, Mg, S, Cu, Zn, Mn and Fe), yield were correlated positively with zinc fractions. Path coefficient analysis indicated that major zinc fractions available to rice are crystalline sesquioxide bound Zn, Res Zn, water soluble plus exchangeable Zn, Organically bound Zn fractions.

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KEY WORDS : Zn-E compost, Zinc, Zinc fractions, Rice, $ZnSO_4$, Nutrient uptake

Zinc application in the enriched form may enhance the fertilizer use efficiency and increase the rice yield. The enrichment of organic manures with micronutrients not only enhances the rate of decomposition but also improves the nutrient status. Application of FYM with $ZnSO_4$ increased the DTPA-Zn content in soils (Devarajan, 1987). Zinc enriched organic manures improves the availability of micronutrients in soil by preventing their fixation and precipitation thereby enhancing the use efficiency of applied zinc, thus saving the cost on fertilizer. Rice is a most important staple food crop in world as well as in India. It serves as a major source of calories for about 60 per cent of the world population. Globally, it occupies an area of 147 m ha with production of 525 mt (Anonymous, 2007). India is the largest rice growing country, while China is the largest producer of rice. Rice provides 32.59 per cent of the dietary energy and 25-44 per cent of the dietary protein. In India, rice is grown in an area of 42.0 m ha with a production of 88.0 m t with an average production of 2.65 t ha^{-1} (Anonymous, 2007).

RESEARCH PROCEDURE

Total zinc was determined by digesting the soil samples with hydrofluoric acid in closed polypropylene bottles.100 mg of soil sample was transferred into a 250 ml polypropylene bottle, 2 ml of aquaregia was added to disperse the sample. Later, exactly 10 ml of hydrofluoric acid was added and the contents were shaken to dissolve the sample for a period of 2 to 8 hr. The residue present after the treatment was dissolved using saturated solution of boric acid and subsequently used for the determination of total Zn by atomic absorption spectrophotometry (Page *et al.*, 1982).

Soil Zn fractions were estimated by subjecting soils to fractionation using different extractions of volume 25 ml each. First 2.5 g soil was treated with 1 M Neutral $Mg(NO_3)_2$, followed by 0.05 M $Cu(OAc)_2$, 0.1M $NH_2OH.HCl$ (pH 2), 0.2 M $(NH_4)_2C_2O_4$ (pH 3) and 0.1

M ascorbic acid with acidified ammonium oxalate to obtain WS+Ex, Org bound, Mn oxide bound, amorphous and crystalline sesquioxide bound zinc fractions, respectively. Residual zinc fraction was calculated by taking difference of total and summation of zinc fractions. The Shuman's (1985) modified method of soil Zn fractionation as given by Chatterjee *et al*. (1992).The extractions were taken in 50 ml polypropylene centrifuge tubes with 2.5 g soil. Between each successive extraction, the supernatant was obtained by centrifuging for 15 min (3000 rpm) and filtering. The concentration of zinc in the extractants was determined by atomic absorption spectrophotometry (Page *et al*., 1982).

The initial soil nutrient status and the composition of the compost used for the experimentation is presented in Table A and B.

Table A : Physical and chemical properties of soil used for the investigation

Parameters	Values
Soil taxonomy	Typic Haplustalf
Sand (%)	69.77
Silt (%)	14.00
Clay (%)	16.23
Texture of soil	Sandy loam
Chemical properties	
pH	4.65
EC (d S m^{-1} at 25^0 C)	0.06
Organic carbon (g kg^{-1})	4.65
CEC (cmol (p+) kg^{-1})	9.88
Available nitrogen (kg ha^{-1})	275.96
Available P_2O_5 (kg ha^{-1})	54.90
Available K_2O (kg ha^{-1})	144.00
Available sulfur (mg kg^{-1})	12.34
Exchangeable calcium [c mol (p^+) kg^{-1}]	5.10
Exchangeable magnesium [c mol (p^+)kg^{-1}]	2.20
DTPA extractable zinc (mg kg^{-1})	0.72
DTPA extractable copper (mg kg^{-1})	2.18
DTPA extractable iron (mg kg^{-1})	38.22
DTPA extractable manganese (mg kg^{-1})	8.85

Table B : Chemical composition of compost used for compost enrichment

Chemical properties	Compost
N (%)	0.80
P (%)	0.41
K (%)	0.68
Calcium (%)	0.51
Magnesium (%)	0.34
Sulfur (%)	0.40
Total zinc (mg kg^{-1})	181.50
Total copper (mg kg^{-1})	78.86
Total iron (mg kg^{-1})	253.06
Total manganese (mg kg^{-1})	113.62

RESEARCH ANALYSIS AND REASONING

The results obtained from the present investigation have been duscussed below:

Distribution of zinc fractions in soil at harvest as influenced by the effect of zinc enriched compost:

The application of zinc enriched compost increased the amount of zinc present in different fractions (Table 1). Increase in amount of zinc present in different zinc fractions might be due to the higher solubility and mobility of the added zinc source. Water soluble plus exchangeable fractions significantly increased with the enrichment of compost (Chitdeshwari and Krishnasamy, 1988).

The amount of zinc in the organically bound form showed an increased in concentration at harvest in all the treatments except control. Such increase is probably due to the release of zinc bound by crystalline sesquioxides on their reduction under submerged condition and its subsequent chelation by organic compounds resulting from anaerobic decomposition of soil organic matter (Hemanthkumar and Basavaraj, 2008).

The manganese oxide bound zinc content varied from 3.22 to 4.16 mg kg^{-1} and no significant difference was observed among the treatments. The low redox potential developed in soils after prolonged submergence favours dissolution of zinc occluded by them making it available to rice plants (Chatterjee *et al*., 1992). The applied amount was found to be converted to this form immediately after application.

All the other treatments recorded significantly higher concentration of amorphous sesquioxide bound zinc. Increase in concentration may be due to oxides of iron, which have high specific surface and, therefore, high adsorption capacity. So the zinc released from other bound forms in soils on submergence might have been adsorbed by such freshly formed amorphous iron oxides resulting in increase in the content of zinc bound by them. About 2.6 to 7.3 per cent of the applied zinc was found to be transformed to this form immediately after application (Chattarjee *et al*., 1992).

Significant differences of crystalline sesquioxide bound zinc were noticed in the zinc applied treatments over control. This fraction dominated other fractions *viz*., water soluble plus exchangeable, organically bound, manganese oxide bound and amorphous sesquioxides bound fractions. This may be due to predominance of crystalline iron oxides in these soils. This fraction exhibits defective structures in which Zn^{2+} can be incorporated to compensate change in valances, there by zinc gets occluded (Vasudeva and Ananthanarayana, 2002).

The submergence caused marked increase in residual zinc content of soil, which indicates considerable transformation of zinc to residual fraction. Similar results were observed by Saha and Mandal (1996) and Hemanthkumar and Basavaraj (2008).

Total zinc content was lowest in control (161.83 mg kg^{-1}). The enriched compost applied plots recorded higher values, followed by package of practices and were superior over control. The increase in total zinc content of soil might be due to application of $ZnSO_4$ along with compost and enriched compost. Similar results were observed by Hemanth kumar and Basavaraj (2008).

Relationship between zinc fractions and soil properties:

The correlation between soil properties and zinc fractions in soil revealed a positive correlation between all the soil chemical properties and different zinc fractions, except manganese oxide bound zinc fraction (Table 2). A positive correlation with OC indicated that some portion of residual zinc obtained from resistant to degrade pool of organic matter (Singh *et al.*, 1998; Vasudeva and Ananthanarayana, 2002). Although total Zn content is considered as poor indicator of the zinc supplying capacity of the soil, it may help for long term nutrient budgeting of a cropping system. Total content of soil zinc depends on the parent material and also attributed to clay content and organic matter of the soil (Gowrishankar and Murugappan, 1998).

Relationship between zinc fractions, yield and nutrients uptake:

The results presented in Table 3 show the relationship between zinc fractions in soil, nutrients uptake and yield of rice. The yield and uptake of nutrients by rice were positively correlated with all the zinc fractions except manganese oxide bound zinc fraction which exhibited a negative correlation with the yield and uptake. This indicates that all the fractions except manganese oxide bound zinc fraction have contributed directly to the yield

Table 1 : Effect of zinc enriched compost on distribution of zinc fractions (mg kg^{-1}) in soil at harvest

Treatments	Ws + Ex	Org. bound	Mn oxide bound	Amor. sesq bound	Cry. sesq bound	Res. Zn	Total Zn
T_1 = NPK alone	1.97	2.94	4.16	2.31	3.28	147.16	161.83
	(1.22)	(1.82)	(2.57)	(1.43)	(2.02)	(90.93)	
T_2 = NPK + Compost	2.22	3.45	3.40	2.36	3.82	148.47	163.72
	(1.36)	(2.11)	(2.08)	(1.44)	(2.33)	(90.68)	
T_3 = NPK + Compost +	2.29	3.61	4.12	2.35	3.74	151.58	167.69
Recommended $ZnSO_4$	(1.37)	(2.15)	(2.46)	(1.40)	(2.23)	(90.39)	
T_4 = NPK + $ZnSO_4$ @ 10 kg ha^{-1}	2.33	3.32	3.80	2.53	3.83	148.94	164.75
	(1.41)	(2.02)	(2.31)	(1.54)	(2.32)	(90.40)	
T_5 = NPK + $ZnSO_4$ @ 15 kg ha^{-1}	2.27	3.39	3.90	2.44	4.19	149.93	166.12
	(1.37)	(2.04)	(2.35)	(1.47)	(2.52)	(90.26)	
T_6 = NPK + $ZnSO_4$ @ 25 kg ha^-1	2.31	3.54	3.22	2.43	4.44	150.87	166.81
	(1.39)	(2.12)	(1.93)	(1.46)	(2.66)	(90.44)	
T_7 = NPK + $ZnSO_4$ @ 30 kg ha^{-1}	2.37	3.73	3.23	2.51	4.32	149.21	165.37
	(1.43)	(2.25)	(1.96)	(1.52)	(2.61)	(90.23)	
T_8 = NPK + Zn-E compost @ 10 kg	2.34	3.74	3.60	2.42	4.51	150.48	167.08
ha^{-1}	(1.40)	(2.24)	(2.15)	(1.45)	(2.70)	(90.06)	
T_9 = NPK + Zn-E compost @ 15 kg	2.52	3.77	3.53	2.47	4.38	150.61	167.28
ha^{-1}	(1.51)	(2.25)	(2.11)	(1.48)	(2.62)	(90.03)	
T_{10} = NPK + Zn-E compost @ 25 kg	2.55	3.79	3.30	2.46	4.58	151.70	168.39
ha^{-1}	(1.51	(2.25)	(1.96)	(1.46)	(2.72)	(90.09)	
T_{11} = NPK + Zn-E compost @ 30 kg	2.48	3.78	3.33	2.52	4.47	150.65	167.23
ha^{-1}	(1.48)	(2.26)	(1.99)	(1.51)	(2.67)	(90.09)	
S.E.±	0.07	0.16	0.36	0.06	0.28	0.79	0.57
C.D. (P=0.05)	0.20	0.49	1.07	0.19	0.82	2.34	NS

(Values in parenthesis indicate percentage of zinc fractions)
Ws + Ex = Water soluble + Exchangeable zinc   Cry. sesq. bound = Crystalline sesquioxide bound zinc
Org. bound = Organically bound zinc, Res. Zn = Residual zinc, Mn oxide bound = Manganese oxide bound zinc
Total Zn = Total zinc   Amor. sesq. bound = Amorphous sesquioxide bound zinc

Table 2 : Correlation coefficient values due to zinc enriched compost between soil properties and zinc fractions of soil at harvest stage

	Ws+ Ex	Org bound	Mn oxide bound	Amor sesq bound	Cry sesq	Res Zn	Total Zn
pH	0.517	0.631*	-0.244	0.323	0.520	0.699*	0.735**
EC	0.417	0.681*	-0.064	0.403	0.448	0.717*	0.828**
OC	0.852**	0.809**	-0.334	0.478	0.674*	0.782**	0.836**
N	0.851**	0.836**	-0.412	0.385	0.755**	0.879**	0.908**
P	0.935**	0.953**	-0.543	0.597	0.838**	0.859**	0.919**
K	0.796**	0.794**	-0.257	0.429	0.547	0.784**	0.817**
Ca	0.661*	0.753**	-0.138	0.358	0.490	0.802**	0.818**
Mg	0.815**	0.879**	-0.449	0.475	0.709*	0.880**	0.899**
S	0.897**	0.888**	-0.423	0.586	0.804**	0.870**	0.929**
Zn	0.835**	0.798**	-0.412	0.720*	0.820**	0.804**	0.875**
Cu	0.927**	0.931**	-0.647*	0.672*	0.834**	0.794**	0.853**
Mn	0.871**	0.919**	-0.521	0.545	0.798**	0.870**	0.911**
Fe	0.917**	0.930**	-0.490	0.624*	0.855**	0.886**	0.948**

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Table 3 : Correlation coefficient values due to zinc enriched compost between zinc fractions, nutrient uptake and yield of rice

	Ws + Ex	Org bound	Mn oxide bound	Amor sesq bound	Cry sesq bound	Res Zn	Total Zn
N	0.797**	0.816**	-0.229	0.475	0.630*	0.892**	0.920**
P	0.775**	0.795**	-0.244	0.405	0.622*	0.913**	0.923**
K	0.803**	0.821**	-0.212	0.445	0.612*	0.891**	0.918**
Mn	0.810**	0.788**	-0.199	0.512	0.640*	0.903**	0.935**
Cu	0.778**	0.786**	-0.154	0.408	0.570	0.889**	0.910**
Zn	0.840**	0.847**	-0.320	0.560	0.697*	0.902**	0.936**
Fe	0.830**	0.860**	-0.270	0.454	0.678*	0.909**	0.943**
Yield	0.778**	0.763**	-0.131	0.437	0.582	0.873**	0.903**

* and ** indicate significance of values at P=0.05 and 0.01, respectively

and uptake of nutrients by rice. A negative correlation and a small direct influence indicate that zinc present in manganese oxide bound fraction is not available to the plants probably due to strong insoluble nature of the fraction.

Contribution of zinc fractions to the total uptake of zinc by rice:

Path co-efficient analysis developed by Li (1956) was applied to the zinc fractionation and total zinc uptake by rice. The results of path co-efficient analysis are given in Table 4. The results revealed that water soluble plus

Table 4 : Path coefficient analysis between total zinc uptake and zinc fractions

	Ws + Ex	Org bound	Mn oxide bound	Amor sesq bound	Cry sesq bound	Res Zn	r values between zinc uptake and zinc fractions
Ws + Ex	**0.3691**	-0.2877	-0.0659	-0.0974	0.9599	0.6726	0.9533**
Org bound	-0.2709	**-0.2425**	-0.1061	-0.0736	0.7400	1.0247	1.0718**
Mn oxide bound	0.2377	0.6660	**-0.0386**	0.3991	-2.8806	0.2696	-1.1952**
Amor sesq bound	-0.3470	-0.2783	-0.2405	**-0.0641**	1.1375	0.8988	1.1064**
Cry sesq bound	-0.3207	-0.2626	-0.1628	-0.1067	**0.6833**	1.0922	0.9227**
Res Zn	-0.2103	-0.3403	0.0143	-0.0789	1.0223	**0.7300**	1.1370**

Residual = 0.3662 **(Bold figures indicate direct effect)**

* and ** indicate significance of values at P=0.05 and 0.01, respectively

Ws + Ex = Water soluble + Exchangeable zinc; Org. bound = Organically bound zinc
Mn oxide bound = Manganese oxide bound zinc; Amor. Sesq. Bound = Amorphous sesquioxide bound zinc
Cry. Sesq. Bound = Crystalline sesquioxide bound zinc; Res. Zn = Residual zinc; Total Zn = Total zinc

exchangeable, crystalline sesquioxibe bound zinc and residual zinc fractions had a positive and direct effect on zinc uptake by rice. Whereas, oraganically bound, manganese oxide bound and amorphous sesquioxide bound zinc fractions showed a negative and direct effect on the zinc uptake. However, water soluble plus exchangeable, oraganically bound, and amorphous sesquioxide bound zinc fractions through manganese oxide bound fraction showed their indirect contribution on total zinc uptake. The major fractions for availability of zinc to plants were in the order as Ws+Ex, org bound, amor sesq bound, cry sesq oxide bound and residual zinc fractions. Sarkar and Deb (1982) and Chidanandappa (2003) also recorded similar observations.

Authors' affiliations:

H.C. PRAKASHA, K.R. ASHOKA AND M.B. MAHENDRA KUMAR, Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, G.K.V.K., BENGALURU (KARNATAKA) INDIA

VIJAY MAHANTHESH AND R. NAGARAJ, Department of Agronomy, University of Agricultural Sciences, G.K.V.K., BENGALURU (KARNATAKA) INDIA

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