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Research Note

Evaluation of Zinc Use Efficiency Using ^{65}Zn Radiotracer Technique in an Alfisol of Turmeric Crop (*Curcuma longa* Var.)

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Abstract: A glasshouse experiment was carried out to investigate the influence of Zinc (Zn) enriched organics and Zn solubilizing bacteria on use efficiency of Zn by turmeric crop and its availability and distribution among various fractions of Zn in the soil using ^{65}Zn isotope. The profound effect of zinc solubilizing bacteria (ZSB) on the increase of dry matter yield of turmeric was found to be 14.0, 14.3 and 18.1 per cent for $ZnSO_4$, Zn enriched FYM and Zn enriched coirpith along with ZSB respectively than consecutive treatments without the organism. In the pot experiment involving ^{65}Zn isotope, the specific activity, per cent Zn derived from fertilizer Zn and uptake of Zn from applied fertilizer and zinc use efficiency were increased intensely with the zinc enrichment treatments than the direct Zn soil application. The zinc use efficiency increased with the Zn treatments, where Zn enriched coirpith performed best (3.48 % in whole plant) than remaining treatments and $ZnSO_4$ alone (0.99 % in whole plant). The organic and exchangeable fractions of Zn revealed the superior nature of Zn fortified with coirpith treatment which surpassed the remaining treatments with its highest specific activity followed by the treatments that received Zn or Fe or Zn + Fe fortified coirpith/FYM than the per se application of $ZnSO_4$ or $FeSO_4$. The per cent distribution of applied Zn fertilizer into the different forms in the soil based on specific activity of Zn to total fraction was in the order of Organic bound Zn > Exchangeable Zn > Manganese oxide bound Zn > Amorphous iron oxide bound Zn > Crystalline iron oxide bound Zn. The tune of increase seen for the per se effect of Zn solubilizing bacteria was markedly higher for organic Zn fraction for the addition of Zn fortified FYM as well as coirpith followed by exchangeable Zn and DTPA Zn.

Key words: Enriched organics, ^{65}Zn isotope, turmeric crop, use efficiency, Zn fractions, Zn solubilizing bacteria.

Introduction

The green revolution has no doubt increased the food and commercial crops production remarkably but post mortem results reveal that it brought with it a trail of problems of micronutrient deficiencies by depleting their available reserve in the soils. The deficiency of Zn is being felt in many parts of India and the world. In India, more than 47 per cent soils have been reported to be deficient in Zn (Katyal and Sharma, 1991) and the figure for Tamil Nadu is 52 per cent. There were frequent reports of iron chlorosis and zinc deficiency in the turmeric crop (Balashanmugham and Chamy, 1989; Madhavi et al., 1995, and Vijayakumar et al., 1997). The use efficiency of applied Zn is very low. The crop recovery values of Zn generally ranged from only 1-2 per cent (Mortvedt, 1994). The escalating cost of fertilizers and concerns on soil health to avoid dumping of chemical fertilizer necessitates the adoption of improved techniques to increase the use efficiency of applied fertilizers. In this regard the use of Zn enriched organics (Anon, 1993; Biju Joseph, 1998) and biological sources like zinc solubilizing bacteria which dissolves the native zinc retains the applied zinc from fixation level in soil (Senthil Kumar, 1997). The objectives of the present study were to determine the Zn use efficiency of Zn enriched manures and zinc solubilizing bacteria combinations using ^{65}Zn studies, to evaluate the effectiveness of zinc solubilizing bacteria to enhance the Zn availability to turmeric crop and to monitor the transformation pattern of applied Zn in various Zn fractions of the soil.

Materials and Methods

A greenhouse experiment was carried out in Radiotracer laboratory, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore, to study the efficiency of Zinc uptake alone as well as in combination with Zn solubilizing bacteria (ZSB), enriched FYM and enriched coirpith on the transformation of applied Zn, yield, content and uptake of Zn and ^{65}Zn use efficiency with turmeric crop (variety BSR 1). Using the principle of isotope dilution technique (IDT) ^{65}Zn tagged $ZnSO_4$ was prepared, taking calculated quantities of analar grade $ZnSO_4$ and ^{65}Zn isotope. The radio isotope was obtained from Bhabha Atomic Research Centre, Trombay as $ZnCl_2$ in dilute HCl medium. The tagged level employed was 2 MBq g^{-1} of Zn.

The FYM and coirpith @ 12.5 t ha^{-1} were enriched with $ZnSO_4$ @ 50 kg ha^{-1}. To the calculated quantity of organic manures specified quantity of tagged $ZnSO_4$ was added and moistened to achieve complete wetness and incubated in closed packets for a period of one month. At the end, samples were drawn and radioactivity was determined taking suitable quantity of extract in scintillation vials. Ten kg of soil was weighed and transferred to earthern pots lined inside with polythene sheet. Plants (three plants per pot) of turmeric were grown in each pot. The experiment was conducted by Completely Randomised Block Design (RBD), with 12 treatments and two replications as given below:

F_1 – Control (Recommended dose NPK),
F_2 – F_1 + FYM,
F_3 – F_1 + FYM + Zn solubilizer(ZSB),
F_4 – F_1 + $ZnSO_4$ @ 50 kg ha^{-1},
F_5 – F_1 + $ZnSO_4$* enriched FYM (1 t FYM ha^{-1}),
F_6 – F_1 + $ZnSO_4$ @ 50 kg ha^{-1} + $FeSO_4$ @ 100 kg ha^{-1},
F_7 – F_1 + $ZnSO_4$+ $FeSO_4$** enriched FYM (1 t ha^{-1}),
F_8 – F_1 + $ZnSO_4$* enriched coir pith (1 t ha^{-1}),
F_9 – F_1 + $ZnSO_4$+ $FeSO_4$** enriched coirpith (1 t ha^{-1}),
F_{10} – F_1 + $ZnSO_4$ + ZSB,
F_{11} – F_1 + Zn enriched FYM + ZSB and
F_{12} – F_1 + Zn enriched coirpith + ZSB.
(*$ZnSO_4$ was applied @ 50 kg ha^{-1} and **$FeSO_4$ @100 kg ha^{-1} to soil).

The crop was planted in September and harvested in April with a duration of 210 days. The FYM @ 12.5 t ha^{-1} and 25 kg N, 60 kg P and 18 kg K ha^{-1} were applied as basal and top dressing of 25 kg N and 18 kg K ha^{-1} were applied each on 30th, 60th, 90th and 120th days after planting. The zinc involving treatments were tagged with ^{65}Zn isotope and enrichment is done in case of FYM and coirpith. Proper plant protection measures were taken as and when needed. The turmeric dry matter content for shoots and rhizomes were recorded after 180 days. The soil and plant samples were analyzed for evaluating Zn availability, concentration and uptake of nutrients by the plants. After harvest, plant parts from each treatment were thoroughly washed, and oven dried at 70°C for 24 h. Dry weights of the shoots and roots were recorded. Five grams of plant samples were taken and were dry ashed in silica crucible and transferred to scintillation vial. The vial was then placed in a well type gamma ray spectrometer (Type GRS 23 B of Electronic Corporation of India Ltd., Hyderabad) and the radioactivity of the samples were determined by differential counting, keeping the single channel analyzer at optimal window and lower level settings. The radioactivity of the fertilizer standards was also determined along with materials, taking suitable quantities in scintillation vials. Using the radioassay data of the plant materials, the following parameters were worked out.

1. Specific activity of plant sample (Cpm or dps mg^{-1} of Zn)

$$= \frac{^{65}\text{Zn radioactivity (ppm)}}{\text{Content of Zn (mg)}}$$

2. Specific activity of fertilizer

$$= \frac{^{65}\text{Zn radioactivity (ppm)}}{\text{Content of Zn (mg)}}$$

3. Per cent Zn derived from fertilizer (% Zn dff)

$$= \frac{[illegible]}{[illegible]} \times 100$$

4. Per cent Zn derived from soil (% Zndfs)
   = 100 – % Zndff
5. Uptake of Zn from applied
   $$= \frac{\%\ Zndff}{100} \times \text{Total uptake of Zn fertilizer (mg pot}^{-1})$$
6. Uptake of Zn from applied soil (mg pot^{-1})
   $$= \frac{[illegible]}{[illegible]} \times \text{Total uptake of Zn (mg pot}^{-1})$$
7. Per cent utilization of applied fertilizer
   $$= \frac{[illegible]}{[illegible]} \times 100$$

All data were subjected to statistical analysis following method suggested by Panse and Sukhatme (1967).

Results and Discussion

Dry Matter Yield and Zinc Content

The data on the dry matter yield of leaves, rhizomes and whole plant showed significant differences for Zn treatments. The Zinc Solubilizing Bacteria (ZSB) exhibited a profound effect on the increase of dry matter yield of turmeric, which was found to be 14.0, 14.3 and 18.1 per cent for $ZnSO_4$, Zn enriched FYM and Zn enriched coirpith along with ZSB than consecutive treatments without the organism (Tables 1 and 2). Whereas the treatment that received ZSB alone without any Zn application found to exhibit significant tune of increase in dry matter (23.2 % in leaves, 49.6 % in rhizomes and 38.2 % in whole plant) than the control (Table 3).

Zinc Content of Various Zn Fractions

All the zinc enrichment treatments were significantly superior than the direct zinc application treatments. An appreciable improvement in manganese oxide bound zinc (MnO-Zn) over control (3.75 mg kg^{-1}) was observed for F_9 (13.50 mg kg^{-1}) which was on par with F_{12} (12.60 mg kg^{-1}) (Table 4). Amorphous iron oxide bound zinc was significantly higher in F_{10} (16.13 mg kg^{-1}) and was on par with F_{12} (15.00 mg kg^{-1}) but control registered the lowest value (5.75 mg kg^{-1}). Crystalline iron oxide bound zinc recorded significantly higher value in F_{11} (14.1 mg kg^{-1}) than the other treatments and the control (7.5 mg kg^{-1}).

The organic bound and exchangeable fractions of Zn revealed superior nature of Zn fortified with coirpith treatment which surpassed the remaining treatments with its highest specific activity followed by the treatments that received Zn or Fe or Zn + Fe fortified coirpith/FYM than the *per se* application of $ZnSO_4$ or $FeSO_4$. The per cent distribution of applied fertilizer into the different forms in the soil based on specific activity of Zn to total fraction was in the order of Organic-Zn > Exchangeable-Zn > Manganous oxide-Zn > Amorphous iron oxide-Zn > Crystalline iron oxide-Zn.

Use Eficiency Prameters

The specific activity of Zn recorded the range values of 327–1667, 337–1094 and 1094–3067 dps mg^{-1} of Zn in leaves, rhizomes and whole plant, respectively (Tables 1, 2 and 3). The specific activity, percent Zn derived from fertilizer Zn and uptake of Zn from applied fertilizer and zinc use efficiency were found to increase intensely with the zinc enrichment treatments than the *per se* application of Zn. The zinc use efficiency concomitantly increased with the Zn treatments, where Zn enriched coirpith performed best (1.3 % in leaves, 1.79 % in

Sequential Extraction Method for Zinc Fractions in Soil done as per the Procedure of Shuman (1985)

Fraction	*Solution*	*Soil (g)*	*Solution (g)*	*Conditions*
Exchangeable	1 M Mg $(NO_3)_2$ (pH 7)	10	40	Shake 2 hrs.
Organic matter	≈ 0.7 M NaOCl (pH 8.5)	10	20	Boiling water bath, 30 min; stir occasionally (Repeat)
Mn oxides	0.1 M NH_2OH. HCl (pH 2)	1[a]	20	Shake 30 min
Amorphous iron oxides	0.2 M $(NH_4)_2C_2O_4$. H_2O – 0.2 M $H_2C_2O_4$ (pH 3)	1	50	Shake 4 hrs in the dark
Crystalline iron oxide	2 M $(NH_4)_2C_2O_4$. H_2O – 0.2 M $H_2C_2O_4$ (pH 3) + 0.1 M ascorbic acid	1	50	Boiling water bath, 30 min; stir occasionally

Table 1: Effect of Zinc Enriched Organics and Zn Solubilizing Bacteria on the Dry Matter Yield, Zn Uptake and Zn Use Efficiency Parameters of Leaves in Turmeric Crop Using ^{65}Zn Isotope

	Dry matter (g pot^{-1})	*Zn content (mg kg^{-1})*	*Specific activity (dps mg^{-1} Zn)*	*Zn derived from fertilizer (%)*	*Uptake of Zn from fertilizer (mg pot^{-1})*	*Zn use efficiency (%)*
F1	9.5	36.3	–	–	–	–
F2	10.3	44.0	–	–	–	–
F3	11.7	49.6	–	–	–	–
F4	12.0	47.1	327	0.9	0.11	0.19
F5	13.7	51.0	573	1.5	0.21	0.37
F6	12.3	45.7	437	1.2	0.14	0.25
F7	14.5	49.0	664	1.8	0.26	0.46
F8	14.1	50.4	861	2.3	0.33	0.58
F9	14.8	48.7	925	2.5	0.37	0.65
F10	12.9	49.6	698	1.9	0.24	0.43
F11	15.0	70.8	1528	4.1	0.62	1.08
F12	16.4	68.4	1667	4.5	0.74	1.30
SE_D	0.98	3.73	87.67	0.24	0.04	0.07
CD (5%)	2.161**	8.22**	202.17**	0.54**	0.09**	0.15**

Table 2: Effect of Zinc Enriched Organics and Zn Solubilizing Bacteria on the Dry Matter Yield, Zn Uptake and Zn Use Efficiency Parameters of Rhizomes in Turmeric Crop Using ^{65}Zn Isotope

	Dry matter (g pot^{-1})	*Zn content (mg kg^{-1})*	*Specific activity (dps mg^{-1} Zn)*	*Zn derived from fertilizer (%)*	*Uptake of Zn from fertilizer (mg pot^{-1})*	*Zn use efficiency (%)*
F1	13.7	48.3	–	–	–	–
F2	16.5	58.6	–	–	–	–
F3	20.5	63.8	–	–	–	–
F4	23.2	60.6	377	1.0	0.24	0.42
F5	27.6	64.5	654	1.8	0.49	0.86
F6	25.0	63.8	378	1.0	0.25	0.45
F7	28.1	64.9	690	1.9	0.52	0.92
F8	29.1	62.7	831	2.2	0.65	1.15
F9	29.8	63.7	843	2.3	0.68	1.19
F10	27.2	63.8	721	1.9	0.53	0.93
F11	32.3	91.3	1058	2.8	0.92	1.62
F12	34.6	89.5	1094	2.9	1.02	1.79
SE_D	1.95	4.84	67.87	0.20	0.06	0.99
CD (5%)	4.28**	10.65**	156.51**	0.46**	0.13**	0.23**

rhizomes and 3.48 % in whole plant) than remaining treatments (0.25-1.08 % in leaves, 0.45-1.62 % in rhizomes and 1.04-3.07 % in whole plant) and $ZnSO_4$ alone treatment (0.19% in leaves, 0.42 % in rhizomes and 0.99 % in whole plant). Thus it lends support to the results of the turmeric field experiment. The pot studies with ^{65}Zn was mainly undertaken to derive some specific conclusions on the impact of zinc solubilizing bacteria on Zn availability, Zn transformation and Zn use efficiency when it is allowed to be present in different situations viz. (i) $ZnSO_4$, (ii) FYM – $ZnSO_4$, (iii) coirpith – $ZnSO_4$ (Table 5). The results emanated for percent zinc use efficiency, specific activity of DTPA Zn, exchangeable Zn, organic Zn were mainly considered. It indicated the positive influence of these organisms on percent Zn use efficiency of added $ZnSO_4$ with more pronounced effect for Zn enriched organics (Coirpith > FYM) through its direct impact on DTPA Zn which in

Table 3: Effect of Zinc Enriched Organics and Zn Solubilizing Bacteria on the Dry Matter Yield, Zn Uptake and Zn Use Efficiency Parameters of whole Plant in Turmeric Crop Using ^{65}Zn Isotope

	Dry matter ($g\ pot^{-1}$)	*Zn content ($mg\ kg^{-1}$)*	*Specific activity ($dps\ mg^{-1}$ Zn)*	*Zn derived from fertilizer (%)*	*Uptake of Zn from fertilizer ($mg\ pot^{-1}$)*	*Zn use efficiency (%)*
F1	23.3	43.4	–	–	–	–
F2	26.8	53.0	–	–	–	–
F3	32.2	58.6	–	–	–	–
F4	35.2	56.0	1094	3.1	1.12	1.98
F5	41.3	60.0	1654	4.6	1.91	3.37
F6	37.3	57.8	1167	3.1	1.18	2.08
F7	42.7	59.5	1776	4.8	2.01	3.55
F8	43.2	58.7	2148	5.7	2.47	4.36
F9	44.6	58.7	2205	6.2	2.86	5.04
F10	40.1	59.2	1847	5.3	2.14	3.78
F11	47.2	84.8	2906	7.3	3.48	6.13
F12	51.0	82.7	3067	7.7	3.95	6.95
SE_D	2.92	4.48	184.1	0.47	0.23	0.40
CD (5%)	6.44**	9.85**	424.5**	1.09**	0.53**	0.92**

Table 4: Effect of Zinc Enriched Organics and Zn Solubilizing Bacteria on the Specific Activity of Zn Fractions in Turmeric Growing Soils Using ^{65}Zn Isotope

	Zn content						*Specific activity of Zinc*					
	DTPA	*Exch*	*Org*	*MnO*	*AmFeO*	*CryFeO*	*DTPA*	*Exch*	*Org*	*MnO*	*AmFeO*	*CryFeO*
F1	0.98	0.47	0.105	3.75	5.75	7.5	–	–	–	–	–	–
F2	1.08	0.42	0.108	4.20	6.25	8.3	–	–	–	–	–	–
F3	1.30	0.45	0.105	5.25	7.25	9.5	–	–	–	–	–	–
F4	1.28	0.41	0.105	9.65	9.75	10.4	4704	7076	13269	4460	6646	5737
F5	1.39	0.44	0.108	9.50	8.75	11.0	5929	9104	18147	2425	4058	3298
F6	1.32	0.43	0.105	10.65	11.00	9.5	4705	6196	15180	4411	5152	6073
F7	1.41	0.45	0.108	11.20	12.25	10.3	6248	9109	20078	1791	3358	2601
F8	1.45	0.46	0.115	11.65	10.00	8.9	6458	9284	20178	1638	3242	2647
F9	1.46	0.45	0.110	13.50	13.50	11.1	6423	9308	21856	1430	2356	2169
F10	1.41	0.45	0.105	11.50	16.13	12.3	6107	8626	20514	2095	2697	3057
F11	1.54	0.46	0.105	10.50	14.50	14.1	6327	9567	23710	1535	1230	1499
F12	1.58	0.47	0.115	12.60	15.00	11.5	6513	10591	21700	1364	1261	1863
SE_D	0.10	0.03	0.01	0.75	0.82	0.79	491.3	717.4	1610.8	241.0	292.4	235.9
CD (5%)	0.23**	NS	NS	1.65**	1.79**	1.74**	1111.5*	1622.8**	3644.0**	545.1**	661.4**	533.7**

turn was considered to be mainly influenced by exchangeable Zn and organic bound Zn. Here again it is worthy to describe that the tune of increase seen for the *per se* effect of Zn solubilizing bacteria was markedly higher for organic Zn fraction for the addition of Zn fortified FYM as well as coirpith followed by exchangeable Zn and DTPA Zn (Senthil Kumar, 1997) in the given order as inferred from the data furnished in Table 5.

On an overall basis, the study reveals that enrichment of FYM and coirpith enhanced the availability of Zn in the soil and uptake by plant, thereby alleviating the Zn deficiency in the crop and sustained potential yield of the crop and positive role of Zn solubilizing organism in enhancing the availability of the nutrients and uptake by crop.

Table 5: Relative Contribution Percentage of Zinc Solubilizing Bacteria to Various Forms of Zinc Application

Parameters		*$ZnSO_4$*	*Zn enriched FYM*	*Zn enriched coirpith*
		Per cent increase over –ZSB		
Zn use efficiency	– ZSB	–	69.9	120
	+ ZSB	90.9	209	251
			(82)	**(69)**
DTPA – Zn	– ZSB	–	26.0	37.2
	+ ZSB	29.8	34.5	38.4
			(6.7)	**(1.0)**
Exchangeable – Zn	– ZSB	–	28.7	31.2
	+ ZSB	21.9	35.2	49.7
			(5.0)	**(14.0)**
Organic – Zn	– ZSB	–	36.8	52.1
	+ ZSB	15.5	78.7	63.5
			(13.1)	**(7.5)**

*Figures within parenthesis indicate the percent increase of +ZSB over -ZSB of respective treatments.

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