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Effect of Zinc Application through Soil and Foliar Means on Bio-fortification of Zinc in Rainfed Maize (*Zea mays* L.)

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ABSTRACT

Field experiments were conducted during 2014 at Agriculture College, Navile, University of Agricultural and Horticultural Sciences, (UAHS) Shivamogga during Kharif 2014, to study the effect of zinc fortified organic manures on yield, quality and nutrient uptake in rainfed maize. The experiment consisted of 12 treatments was laid out in Randomized Complete Block Design (RCBD) and replicated thrice. The treatments comprise of zinc fertilization through zinc enriched maize residue compost, FYM, soil and foliar means were compared with recommended dose of fertilizer alone and recommend package of practice. In the present experiment significantly higher grain (60.9 q ha^{-1}) and stover yields (62.57 q ha^{-1}) was recorded with application of 7.5 t of Maize Residue Compost (MRC) enriched with 15 kg $ZnSO_4$ on account of significantly higher test weight (31.51 g) and grain yield plant^{-1} (134.7 g plant^{-1}). Again, total dry matter production (326.38 g plant^{-1}) and uptake of nitrogen (124.11 kg ha^{-1}), phosphorous (24.87 kg ha^{-1}), potassium (149.36 kg ha^{-1}) and zinc (451.51 g ha^{-1}) were also significantly higher with application of 7.5 t of Maize Residue Compost enriched with 15 kg $ZnSO_4$. With regards to quality parameters of maize significantly higher grain zinc content (46.67 mg kg^{-1}), soluble protein in grain(5.39 mg kg^{-1}), crude protein content (12.67 %) and protein yield (760.14 kg ha^{-1}) of maize was also higher with application of 7.5 t of Maize Residue Compost enriched with 15 kg $ZnSO_4$.

Key words: *Biofortification, Enriched MRC, Foliar Application, Uptake, Quality, Zinc.*

INTRODUCTION

Maize occupies a pride place among the cereals in India. India grows about 9.4 mha of maize with total annual production of 23.7 mt of grain giving an average yield of 2.55 t ha^{-1}[2] that is tremendously lower than other maize growing countries of the world. Reasons for yield gap in maize could be mainly due to inadequate and imbalanced fertilization.

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In general attention towards the major nutrient is more than the secondary and micronutrient, but in maize zinc nutrition plays a major role in plant metabolism and yielding potential. However, less awareness about micronutrients application and indiscriminate use of major nutrients led to the imbalance in soil nutrient states and as a result micronutrients deficiency is noticed in many parts in general and zinc in particular. It has been estimated that the extent of zinc deficiency is nearly 48.5 and 72.8% of the soils at national level and in Karnataka, respectively[5]. According to the recent survey, zinc deficiency in human nutrition is the most wide spread nutritional disorder, next only to iron, vitamin 'A' and iodine[1]. Nearly, 49% of the global population does not meet their daily-recommended intake of 15 mg day^{-1} of zinc for an adult and is one of the leading risk factors associated with diseases such as diarrhoea and retarded growth contributing to the death of 8,00,000 people each year[3]. Zinc enriched compost application to growing plants react with native reserves of micronutrient elements and renders them available to the plants. Further, the beneficial effect of the materials on soil structure, nutrient retention capacity and their bio-regulatory roles in soil. Hence, a need was felt to study the effects of zinc fortified organic manure on productivity, quality and nutrient uptake of maize under rainfed ecosystem. Therefore a field experiment was conducted during *kharif* 2014 and the salient findings of the present investigations are discussed in the present paper.

MATERIALS AND METHODS

A field experiment was conducted in 2014; to study the effect of zinc enriched farmyard manure, maize residue compost and foliar feeding of $ZnSO_4$ on growth, yield and economics of maize (*Zea mays* L.) in Southern Transitional Zone of Karnataka.

The experiment consisted of twelve treatments Viz., $ZnSO_4$ @ 10 kg ha^{-1}+FYM (7.5 t ha^{-1}), $ZnSO_4$ @ 15 kg ha^{-1}+FYM (7.5 t ha^{-1}), $ZnSO_4$ @ 10 kg ha^{-1} through enriched FYM (7.5 t ha^{-1}), $ZnSO_4$ @ 15 kg ha^{-1} through enriched FYM (7.5 t ha^{-1}), $ZnSO_4$ @ 10 kg ha^{-1} through enriched MRC (7.5 t ha^{-1}), $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1}), foliar application of $ZnSO_4$ (0.5%) at 20 DAS, foliar application of $ZnSO_4$ (0.5%) at 40 DAS, foliar application of $ZnSO_4$ (0.5%) both at 20 and 40 DAS and RDF+FYM (7.5 t ha^{-1}), without zinc enrichment RDF+FYM (7.5 t ha^{-1}) and RDF alone were replicated thrice using Randomized Complete Block Design (RCBD). Before taking up the field experiment the required amount of maize residue compost and farmyard manure was prepared. Maize residue was collected and chopped in to small pieces of about 4 to 5 inches size. Windrow method was followed for composting, where the materials were added layer by layer. The dimension of the compost pit was 6 ft width and 12 ft length. Each layer consists of maize straw filled to a height of 12" then rock phosphate and press mud were spread uniformly, followed by addition of urea and zinc sulphate. The consortia of microorganisms as composting culture (micro-organisms such as *Trichoderma*+*plurotus* Spp) along with green leaves were spread uniformly to facilitate quick decomposition. Water was sprinkled at every layer in order to maintain the required moisture. In the same order the materials were filled for 5-6 layers. After the piling of all layers, the heap was plastered using mud to maintain anaerobic condition. The optimum moisture was maintained (50 to 60%) by sprinkling water once in two days to fasten the decomposition rate. The first turning was given after 20 days for aeration. After that, another two turnings were given in 15 days interval. A commonly prepared FYM was used for the zinc enrichment. The material used in compost preparation and its quantity is given in Table 1. The zinc enrichment was made to well decompose FYM by mixing a known quantity $ZnSO_4$, $7H_2O$ as treatment^{-1} details (10 and 15 kg $ZnSO_4$ ha^{-1}). The compost will be left for curing with intermittent mixing and maintenance of ideal moisture for 15 days. The prepared zinc enriched FYM and MRC was incorporated into the soil 10 days before sowing of maize.

The nutrient composition of zinc enriched compost is presented in Table 2. In case of treatments T_1 and T_2, zinc sulphate @ 10 and 15 kg ha^{-1}, respectively, was applied to the soil on the day of sowing. For foliar application of zinc nutrition treatment plots $ZnSO_4$ at 0.5% concentration was sprayed as treatment^{-1} details.

The physical and chemical properties of soil of the experimental site was analysed from composite soil sample collected from a depth of 0-30 cm. The experimental site is red sandy loam in texture with 81.1% of sand, 7.4% of silt, and 11.5% of clay. The soil was found to be acidic in reaction (pH 5.91) with a normal electrical conductivity of 0.10 d Sm^{-1} and medium in organic carbon (0.55%). The soil is low in available nitrogen (232 kg ha^{-1}), high in available phosphorus (77.40 kg ha^{-1}) and medium in available potassium (193.50 kg ha^{-1}). The application recommended dose chemical fertilizers (100:50:25 kg NPK ha^{-1}) for each treatment using urea, SSP and MOP. Observations on growth, yield attributes, grain and stover yields were recorded as the standard^{-1} procedure. The cost of cultivation, gross, net returns and benefit: cost ratios were calculated on the basis of prevailing market price of different input and output. Data were statistically analyzed as suggested by Gomez and Gomez[4].

Table 1: Materials used in preparation of maize residue compost (MRC)

Materials	Quantity
Maize residue	1000 kg
Rock phosphate	20 kg
Press mud	300 kg
Green leaves	100 kg
Compost culture (*Trichoderma*+*Plurotus* Spp.)	200 g
Urea	5 kg
Zinc sulphate	250 g
Red earth	600 kg

Table 2: Nutrient composition of enriched manures

Sources	Nitrogen (%)	Phosphorus (%)	Potassium (%)	$ZnSO_4$ (ppm)
Farm Yard Manure (FYM)	0.56	0.25	0.37	1.35
FYM enriched with Zinc @ 10 kg ha^{-1}	0.58	0.25	0.38	6.38
FYM enriched with Zinc @ 15 kg ha^{-1}	0.59	0.26	0.39	8.19
Maize Residue Compost (MRC)	0.52	0.36	0.50	3.26
MRC enriched with Zinc @ 10 kg ha^{-1}	0.53	0.35	0.52	7.54
MRC enriched with Zinc @ 15 kg ha^{-1}	0.56	0.36	0.54	8.92

At harvest the grain and stover samples were dried at 68° C, pulverized and digested using diacid mixture containing HNo_3 and HCl_4 in the proportion of 10:4 and zinc concentration in the digest was determined by spetrophotometric method[10]. Total nitrogen of plant samples was estimated by Kjeldal's method and digesting the plant samples with diacid mixture, total phosphorus and potassium concentration in the digest were determined by vanadomolybdate yellow colour method and flame photo meter respectively[6]. The application recommended dose fertilizer (100:50:25 kg NPK ha^{-1}) for each treatment was applied as the calculation by using urea, SSP and MOP fertilization.

The uptake of these nutrients was computed with the following formulae viz.

Zinc estimation: Uptake (g ha^{-1}) = nutrient content (ppm) × dry matter yield (kg ha^{-1}) × 1/1000

For other nutrients**:**

Nutrient Uptake (kg ha^{-1}) = nutrient concentration (%) × dry matter yield (kg ha^{-1})

RESULTS AND DISCUSSION

Growth and yield

Among the growth attributes of maize, total dry matter production indicates the productivity potential of the crop[8]. In the present investigation significantly higher total dry matter production at harvest was recorded with application of $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1}) over rest of the treatments, increased dry matter production further reflected in improvement in yield attributing character, in maize cob length, cob girth, number of grain rows cob^{-1}, number grins row^{-1} and test weight are the manifestation of yield potentiality of grain yield $plant^{-1}$. In the present investigation application of $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1}) recorded significantly higher test weight (31.51 g), cob diameter (15.49 cm) and grain yield $plant^{-1}$ (134.7 g). Further, because of significance excellence in grain yield $plant^{-1}$ application of $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1}) has recorded significantly higher grain (60.9 q ha^{-1}) and stover (62.5 q ha^{-1}). Significant improvement in productivity of maize in the present treatment combination could be due to direct and sustained availability of zinc along with major nutrients might have taken part in nourishment of crop and also increased activity of meristamatic cells and cell elongation interns lead to better vegetative growth in terms of increased plant height and number of leaves eventually contributed to the increased dry matter production. Similar results of increase in growth characters with zinc application were reported by Shanmugam and Veeraputhran[12] and Ranjbar and Bahmaniar[11].

Nutrient uptake

Nutrient uptake by crop is the product of total dry matter production and nutrient concentration in plant tissue. From the present study it was noticed that application of $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1}) recorded significantly higher total nitrogen (124.11 kg ha^{-1}), phosphorus (24.87 kg ha^{-1}), potassium (149.36 kg ha^{-1}) and zinc (451.51 g ha^{-1}) uptake of maize when compared to rest of the treatments (Table 4). Further, data on nutrient acclimation in maize indicated that, application of $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1}) recorded significantly higher amount of nitrogen (35.33 kg ha^{-1}), phosphorus (4.91 kg ha^{-1}), potassium (48.67 kg ha^{-1}) and zinc (250.93 g ha^{-1}) than rest of the treatments combinations. It could be due to increased availability of nutrients in zinc enriched compost and consequent increase in the grain stover yield of plants (Table 3). Zinc plays a vital role in plants ability to use nitrogen and potassium is transformation into yield and protein synthesis. Application of zinc through compost causes higher phosphorus uptake due to higher availability of the plant nutrients from the soil reservoir and additional quantity of nutrients supplied by compost, compared to direct soil application. It also helps in creating more favorable conditions either through increased solubility in soil solution or by possible stimulation of root absorption. The results are in line with the findings of Mani *et al*[7]., and Nandan[9] .

Quality

Zinc acts as an activator of many enzymes in plants and is directly involved in the biosynthesis of metabolites; physiologically determinate nature of maize would mobilize and accumulate in sink. The significantly higher grain zinc content (46.67 mg g^{-1}), soluble proteins content of grain (5.39 mg g^{-1}), crude protein (12.67 %) and protein yield (760.14 kg ha^{-1}) was recorded with application of $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC 7.5 t ha^{-1}. These findings are in close agreement with the findings of Tahir *et al*[13].

Table 3: Growth parameter of maize as influenced by application of zinc in different method

Treatments	Total dry matter (g plant^{-1})	Cob diameter (cm)	Test wt. (g)	Grain yield plant^{-1}(g)	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Net income (Rs ha^{-1})	B:C
T_1. FYM (7.5 t ha^{-1})+$ZnSO_4$ @ 10 kg ha^{-1}	277.79	14.07	25.60	116.4	49.9	54.21	22732	1.90
T_2. FYM (7.5 t ha^{-1})+$ZnSO_4$ @ 15 kg ha^{-1}	281.73	14.20	27.73	119.6	50.4	55.24	28078	2.11
T_3. $ZnSO_4$ @ 10 kg ha^{-1} through enriched FYM (7.5 t ha^{-1})	306.48	14.46	28.40	125.4	56.5	59.54	41040	2.37
T_4. $ZnSO_4$ @ 15 kg ha^{-1} through enriched FYM (7.5 t ha^{-1})	322.09	15.55	30.73	132.6	59.2	60.98	44159	2.46
T_5. $ZnSO_4$ @ 10 kg ha^{-1} through enriched MRC (7.5 t ha^{-1})	320.06	15.39	29.14	127.4	58.6	61.44	43664	2.45
T_6. $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1})	326.38	15.49	31.51	134.7	60.9	62.57	46286	2.53
T_7. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5 %) at 20 DAS	279.16	15.27	26.00	118.1	51.8	58.19	40400	2.62
T_8. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5 %) at 40 DAS	277.12	15.37	27.51	119.4	52.0	59.43	40709	2.63
T_9. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5 %) both at 20 and 40 DAS	298.93	15.49	29.94	125.0	55.8	61.09	45160	2.79
T_{10}. FYM (7.5 t ha^{-1}) without zinc enrichment	276.01	13.85	27.35	120.60	49.2	53.79	32318	2.31
T_{11}. MRC (7.5 t ha^{-1}) without zinc enrichment	284.65	14.10	29.14	121.9	50.4	54.3	32792	2.28
T_{12}. RDF alone	228.47	12.76	22.11	98.4	47	53.02	19206	1.87
SEm±	7.05	0.52	1.60	5.79	2.69	2.09		
CD (p=0.05)	20.68	1.53	4.69	17.00	7.91	6.13		

Note: MRC: Maize Residue Compost FYM: Farm Yard Manure
DAS: Days after Sowing RDF: Recommended Dose of Fertilizer

Table 4: Grain zinc content, soluble protein, crude protein, and protein yield of maize as influenced by method and levels of zinc application

Treatments	Grain zinc content	Soluble protein in grain	Crude protein	Protein yield
	mg kg^{-1}	mg g^{-1}	%	kg ha^{-1}
T_1. FYM (7.5 t ha^{-1})+$ZnSO_4$ @ 10 kg ha^{-1}	34.03	4.70	10.46	512.37
T_2. FYM (7.5 t ha^{-1})+$ZnSO_4$ @ 15 kg ha^{-1}	37.63	5.00	10.83	528.80
T_3. $ZnSO_4$ @ 10 kg ha^{-1} through enriched FYM (7.5 t ha^{-1})	37.33	4.88	10.93	558.33
T_4. $ZnSO_4$ @ 15 kg ha^{-1} through enriched FYM (7.5 t ha^{-1})	40.60	5.13	11.99	700.72
T_5. $ZnSO_4$ @ 10 kg ha^{-1} through enriched MRC (7.5 t ha^{-1})	39.00	4.93	12.11	637.05
T_6. $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1})	46.67	5.39	12.67	760.14
T_7. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5 %) at 20 DAS	38.93	4.91	10.62	572.74
T_8. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5 %) at 40 DAS	38.57	4.83	10.69	591.34
T_9. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5 %) both at 20 and 40 DAS	43.00	5.10	11.64	645.96
T_{10}. FYM (7.5 t ha^{-1}) without zinc enrichment	25.40	3.90	10.39	504.03
T_{11}. MRC (7.5 t ha^{-1}) without zinc enrichment	30.17	4.23	10.58	505.27
T_{12}. RDF alone	20.24	2.93	9.56	423.53
SEm$\pm$	3.21	0.23	0.50	24.88
CD (p=0.05)	9.43	0.69	1.46	72.99

Note: MRC: Maize Residue Compost FYM: Farm Yard Manure

DAS: Days after Sowing RDF: Recommended Dose of Fertilizer

Table 5: Grain and total nitrogen, phosphorous, potassium and zinc uptake by maize plant as influenced by method and levels of zinc application

Treatments	Nitrogen uptake kg ha^{-1}		Phosphorous uptake kg ha^{-1}		Potassium uptake kg ha^{-1}		Zinc uptake g ha^{-1}	
	Grain	Total	Grain	Total	Grain	Total	Grain	Total
T_1. FYM (7.5 t ha^{-1})+$ZnSO_4$ @ 10 kg ha^{-1}	25.44	88.60	3.10	11.88	30.46	84.83	170.17	304.22
T_2. FYM (7.5 t ha^{-1})+$ZnSO_4$ @ 15 kg ha^{-1}	26.40	93.27	3.31	16.62	32.54	93.95	189.75	336.88
T_3. $ZnSO_4$ @ 10 kg ha^{-1} through enriched FYM (7.5 t ha^{-1})	28.09	102.69	4.13	20.30	42.10	115.47	215.33	378.93
T_4. $ZnSO_4$ @ 15 kg ha^{-1} through enriched FYM (7.5 t ha^{-1})	32.06	116.10	5.73	22.73	36.98	131.35	241.77	417.71
T_5. $ZnSO_4$ @ 10 kg ha^{-1} through enriched MRC (7.5 t ha^{-1})	33.71	117.52	3.92	21.29	37.78	132.61	227.12	396.79
T_6. $ZnSO_4$ @ 15 kg ha^{-1} through enriched MRC (7.5 t ha^{-1})	35.33	124.11	4.91	24.87	48.67	149.36	250.93	451.51
T_7. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5%) at 20 DAS	26.43	95.58	3.82	19.11	29.82	108.92	196.18	355.87
T_8. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5%) at 40 DAS	26.52	97.90	4.30	20.30	33.77	116.28	198.05	362.29
T_9. FYM (7.5 t ha^{-1})+Foliar application of $ZnSO_4$ (0.5%) both at 20 and 40 DAS	34.83	110.49	5.19	21.02	41.06	127.36	245.84	430.62
T_{10}. FYM (7.5 t ha^{-1}) without zinc enrichment	24.51	87.10	2.61	10.52	23.42	78.54	122.83	226.15
T_{11}. MRC (7.5 t ha^{-1}) without zinc enrichment	25.93	89.98	1.78	11.43	21.42	82.61	154.88	277.04
T_{12}. RDF alone	22.90	80.16	1.66	7.44	19.85	64.77	100.37	185.68
SEm$\pm$	1.88	4.74	0.66	2.79	5.36	7.37	6.39	5.05
CD (p=0.05)	5.52	13.91	1.95	8.20	15.73	21.63	5.74	14.81

Note: MRC: Maize Residue Compost FYM: Farm Yard Manure

DAS: Days after Sowing RDF: Recommended Dose of Fertilizer

CONCLUSION

Applications of zinc through enriched compost would be a very useful strategy to keep readily available zinc in soil during plant growth in order to ensure healthy root growth and to maintain adequate root zinc absorption from soil. It was concluded from the present investigation is that, application of $ZnSO_4$ @ 15 kg ha^{-1} through enriched maize residue compost (MRC) 7.5 t ha^{-1} significantly improved the yield, nutrient uptake and grain quality parameters in rainfed maize.

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