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Nutrient Uptake of Maize as Influenced by Integrated Approach for Zinc Enrichment

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ABSTRACT

A field experiment on 'Nutrient uptake of maize as influenced by integrated approach for zinc enrichment' was conducted at College farm, College of Agriculture, PJTSAU, Rajendranagar, Hyderabad during *kharif* 2019-2020. The experiment was laid out in Randomized Block Design with 10 treatments and replicated thrice. The soil of experimental site was sandy loam type, slightly acidic in pH (6.30), non-saline in EC (0.21 dSm^{-1}), low in organic carbon (0.42%), low in available N (230.60 kg ha^{-1}), medium in available P (24.30 kg ha^{-1}), high in available K (388.40 kg ha^{-1}) and low in available Zn (0.54 ppm). The results revealed that total N (219.27 kg ha^{-1}), P (94.83 kg ha^{-1}), K (237.38 kg ha^{-1}) and Zn (771.78 g ha^{-1}) uptake recorded highest with T_5 (RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}) and it was on par with T_7 (RDF + ZSB (1kg/100 kg FYM) + 0.2% foliar spray of $ZnSO_4$ at Knee-high and Tasseling stages) while the lowest uptake were recorded with T_1 (RDF alone (Control-N: P_2O_5: K_2O @ 200:60:50 kg ha^{-1})).

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INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereal crop next to wheat and rice in India, which contributes nearly 9% to the national food basket (Hasanain *et al.* 2021). It is cultivated in both tropical and temperate regions of the world. Maize is called as "miracle crop" because of its higher productive potential compared to any other cereal crop (Paramasivan *et al.* 2012). Maize is the most important cereal feed for livestock and critical staple food for people living in Asia, Africa and Latin America. Maize grains utilized in many ways like making roti, rawa, maida, popcorn and some industrial products like protein foods, glucose powder, starch. Beside this, stover serves as a good fodder for cattle. Hence, it is proudly known as "queen of cereals" (Baradhan and Kumar 2018). Maize is cultivated in all season's viz, *kharif, rabi* and *summer*.

On an average maize grain is composed of 60% carbohydrate, 10% protein, 4.5% oil, 3.5 3% fiber and 2% minerals. It also contains 348 mg P, 286 mg K, 114 mg S, 10 mg Ca, 2.3 mg Fe and 90 microgram of carotene per 100g grain. Zinc performs exclusively large number of key functions; as it is important for human health, it is also called "metal of life" (Mu-

hammad and Abdul 2019). At present about 48.1% of Indian soils are deficient in diethylene-tri amine pent acetate (DTPA) extractable zinc. Zinc (Zn) and iron (Fe) deficiencies are well-documented public health issue and an important soil fertility constraint to crop production. Generally, there is a close geographical overlap between soil deficiency and human deficiency of Zn indicating a high requirement for increasing concentrations of micronutrients in food crops (Kumar and Salakinkop 2018).

Studies indicated that it is possible to increase Zn concentration in maize grain by either soil Zn application or seed priming with Zn in South Asia. Maize seed priming with 1% $ZnSO_4$ not only enhanced plant growth but also increased the final grain yield and seed Zn contents in plants grown on soil with limited Zn availability (Hossain *et al.* 2008). Foliar application of macro and micro nutrients at critical stages of crop growth facilitates for quick supply of nutrients, thereby promoting photosynthesis and mobilization of assimilates to sink and ultimately the yield (Sharma *et al.* 2013). In this context, the information is not available on comparative performance of different zinc sources and method of application of zinc in maize for increased crop productivity. Hence, the present field study was undertaken to identify the most suitable source of zinc and method of application of zinc in maize during *kharif* season.

MATERIALS AND METHODS

The experiment was conducted during *kharif*, 2019-2020 at College farm, Plot no. B-8, Block-B, College of Agriculture, Rajendranagar, Professor Jayashankar Telangana State Agricultural University, Hyderabad. The geographical location of the experimental site was 17°19' 19.2" N Latitude, 78°24' 39.2" E Longitude with an altitude of 542.3 m above mean sea level. Agro-climatologically the area is classified as Southern Telangana Agro Climatic Zone of Telangana State. The total rainfall received during the cropping period was only 680.8 mm.

The field was ploughed twice with tractor drawn cultivator followed by levelling with rotavator. Crop was sown on ridges. The recommended dose of fertilizers applied (N, P and K @ 200: 60: 50 kg ha-^{1}). Maize hybrid nk-6240 @ 20 kg ha-^{1} was sown. In present experiment the spacing was 60 cm × 20 cm. Pre-emergence herbicide like atrazine 50% WP was sprayed @ 2-2.5 kg ha-^{1}. Intercultural operations like gap filling, thinning and weeding was done timely. Crop was entirely grown under rainfall. The crop was harvested at proper stage of maturity as determined by visual observations. Border rows from all sides of each plot were first harvested followed by net plot. Fresh and dry weights of cobs and stover were weighed separately. Shelling of cobs was done by tractor operated maize sheller machine. Biometric observations recorded were nutrient uptake, grain and stover yield.

The treatment details include recommended dose of fertilizer (RDF- 200: 60: 50-N: P_2O_5: K_2O kg ha-^{1}) N was applied in three equal splits (at sowing, knee-high and tasseling stage), total P was applied as basal and K was applied in two equal splits (at sowing and tasseling stage). FYM alone was applied to T_3 and T_8 treatments, FYM was enriched with zinc solubilising bacteria (ZSB) @ 1 kg per 100 kg FYM for about 22 days before sowing i.e., T_2 and T_7 and FYM is enriched with ZnSO4 @ 50 kg ha-^{1} with 25 t FYM ha-^{1} for about 22 days before sowing i.e., T_5 and T_{10}. Seed pelleting (1kg seed) was done by adding water with 3.6 g of $ZnSO_4$, after proper dissolving, polymer was added to above solution and made into slurry by thorough stirring. The slurry was added to 1 kg seed in a polythene cover and thoroughly mixed for 4-5 minutes and shade dried i.e., T_4 and T_9.

RESULTS AND DISCUSSION

Nitrogen uptake (kg ha-^{1})

Nitrogen being a structural component of proteins involved in various biological functions. At all stages of crops i.e, 30 DAS, knee-high, 60 DAS and at harvest the nitrogen uptake recorded highest in T_5 (RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}) and it was on par with T_7 (RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)) in most of the stages and the lowest was registered with T_1 (RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}) in grain, stover & total (grain + stover) (Table 1).

Table 1. Nitrogen uptake (kg ha^{-1}) as influenced by integrated approach for zinc enrichment in maize.

Treatments	Nitrogen uptake (kg ha^{-1})					
	30 DAS	Knee-high stage	60 DAS	At harvest		
				Grain	Stover	Total
T_1 - RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}	4.99	10.36	39.33	52.82	72.35	125.17
T_2 - RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	9.05	19.36	80.37	88.53	92.81	181.34
T_3 - RDF + FYM (25 t ha^{-1})	6.76	16.14	65.61	86.59	92.76	179.35
T_4 - RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	8.72	17.07	77.75	92.79	90.18	182.97
T_5 - RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	11.26	24.36	114.99	99.60	119.66	219.27
T_6 - RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	5.80	13.61	50.03	55.68	76.62	132.30
T_7 - RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	8.27	22.50	112.69	97.58	116.41	213.99
T_8 - RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	7.09	17.68	62.23	72.51	81.82	154.33
T_9 - RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	8.48	17.54	71.03	81.79	84.79	166.58
T_{10} - RDF + FYM enrichment with 50 kg ZnSO4 ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	10.67	18.35	97.96	91.08	99.21	190.29
SEm±	0.45	0.88	5.27	2.85	2.86	4.42
CD (p=0.05)	1.35	2.63	15.77	8.53	8.56	13.24

The higher uptake of nitrogen might be due to favourable influence of nitrogen on higher degree of root proliferation, anchorage and deep penetration which in turn absorb higher amount of nutrients from the rhizosphere and supply to the crop resulting in higher dry matter production. Similar results were earlier reported by Paramasivan *et al.* (2012) and Palai *et al.* (2017).

Table 2. Phosphorus uptake (kg ha^{-1}) as influenced by integrated approach for zinc enrichment in maize.

Treatments	Phosphorus uptake (kg ha^{-1})					
	30 DAS	Knee-high stage	60 DAS	At harvest		
				Grain	Stover	Total
T_1 - RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}	0.56	0.73	2.25	51.86	6.82	58.68
T_2 - RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	0.97	1.55	4.56	67.48	11.83	79.31
T_3 - RDF + FYM (25 t ha^{-1})	0.71	1.38	4.91	59.43	10.42	69.85
T_4 - RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	0.94	1.76	4.21	66.52	10.64	77.15
T_5 - RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	1.71	2.51	8.15	79.31	15.52	94.83
T_6 - RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	0.48	1.04	2.84	53.33	7.58	60.91
T_7 - RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	1.06	2.31	7.02	76.34	14.29	90.63
T_8 - RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	0.77	1.75	3.76	55.18	8.16	63.34
T_9 - RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	0.92	1.30	4.24	62.82	9.83	72.65
T_{10} - RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	0.97	1.73	5.81	70.00	12.98	82.98
SEm ±	0.09	0.12	0.38	2.19	0.65	2.39
CD (p=0.05)	0.26	0.38	1.14	6.55	1.94	7.16

Table 3. Potassium uptake (kg ha^{-1}) as influenced by integrated approach for zinc enrichment in maize.

Treatments		Potassium uptake (kg ha^{-1})					
		30 DAS	Knee-high stage	60 DAS	At harvest		
					Grain	Stover	Total
T_1 -	RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}	9.48	18.44	57.57	15.19	113.50	128.70
T_2 -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	13.67	25.74	84.48	22.35	165.87	188.23
T_3 -	RDF + FYM (25 t ha^{-1})	10.41	26.03	77.07	24.43	162.56	186.98
T_4 -	RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	13.10	26.46	80.19	25.87	163.74	189.61
T_5 -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	19.54	33.14	101.21	30.78	206.60	237.38
T_6 -	RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	9.62	20.96	61.21	16.13	116.19	132.33
T_7 -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	17.45	30.11	97.61	29.01	194.97	223.99
T_8 -	RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	15.20	24.69	79.31	20.44	119.37	139.81
T_9 -	RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	14.87	25.38	72.97	23.02	137.95	160.97
T_{10} -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	18.26	28.28	92.73	22.65	192.53	215.18
	SEm±	0.97	1.21	3.02	0.79	12.56	12.52
	CD (p=0.05)	2.92	3.63	9.05	2.37	37.59	37.49

Phosphorous uptake (kg ha^{-1})

An overview of the data indicated that, phosphorous uptake differed significantly at 30 DAS, knee high stage, 60 DAS and at harvest due to treatments (Table 2). Similar to N uptake, P uptake in grain, stover & total (grain + stover) at all stages of crop was highest in T_5 (RDF + FYM enrichment with 50 kg $ZnSO_4$ ha-^{1}) followed by T_7 (RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and

Table 4. Zinc uptake (g ha^{-1}) as influenced by integrated approach for zinc enrichment in maize.

Treatments		Zinc uptake (g ha^{-1})					
		30 DAS	Knee-high stage	60 DAS	At harvest		
					Grain	Stover	Total
T_1 -	RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha^{-1}	6.02	15.63	101.42	106.32	241.41	347.74
T_2 -	RDF + Zinc Solubilising Bacteria (ZSB @ 1kg/100 kg FYM)	11.82	29.65	197.48	191.40	410.34	601.73
T_3 -	RDF + FYM (25 t ha^{-1})	8.84	30.66	166.02	182.80	389.06	566.41
T_4 -	RDF + Seed pelleting (3.6 g $ZnSO_4$ kg^{-1} seed)	11.99	30.65	172.86	193.61	410.93	604.53
T_5 -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1}	17.63	42.66	304.59	246.80	506.70	771.78
T_6 -	RDF + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	6.82	18.74	116.35	117.53	275.30	392.83
T_7 -	RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	11.91	38.62	256.50	230.48	461.97	704.06
T_8 -	RDF + FYM (25 t ha^{-1}) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	8.29	25.42	134.97	148.26	313.73	441.10
T_9 -	RDF +Seed pelleting + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	9.29	24.06	147.10	165.93	344.94	493.52
T_{10} -	RDF + FYM enrichment with 50 kg $ZnSO_4$ ha^{-1} + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)	13.69	36.16	232.74	222.34	449.33	671.67
	SEm±	0.83	2.02	10.37	7.45	12.82	17.21
	CD (p=0.05)	2.48	6.04	31.04	22.14	38.37	51.53

Tasseling stages)) which were on par with each other but significantly superior over rest of the treatments. The lowest phosphorous uptake was registered with T_1 (RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha-^{1}) at all stages of crop growth.

The better performance of T_5 and T_7 treatments might be due to the higher proportion of phosphorus present in soil and through application of organic manures like FYM, which would have promoted root growth, enhanced the utilization of soil nutrients and water by plants that resulted to increased uptake of phosphorus. These results are in conformity with the results of Paramesh *et al*. (2014).

Potassium uptake (kg ha^{-1})

The significantly higher K uptake in grain, stover and total (grain + stover) by maize was recorded with T_5 (RDF + FYM enrichment with 50 kg $ZnSO_4$ ha-^{1}) and was on par with T_7 (RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)). The lowest potassium uptake was obtained with T_1 (RDF alone (Control) N: P2O5: K_2O - 200:60:50 kg ha-^{1}) treatment (Table 3).

The increased potassium uptake might be due to the higher proportion of potassium in the soil, which met the crop demand at important growth phases like tassel emergence and dough stage. In addition the higher photosynthetic activity in leaf exerted by multi-nutrients present in the soil and through foliar application which indirectly leads in efficient utilization of nutrients applied to the soil. Satish *et al.* (2011) and Paramasivan *et al*. (2012) reported similar results earlier.

Zinc uptake (g ha-^{1})

Perusal of the data indicated that zinc uptake differed significantly at 30 DAS, knee high stage, 60 DAS and at harvest were presented in Table 4. The significantly higher Zn uptake in grain, stover and total (grain + stover) by maize was recorded with T_5 (RDF + FYM enrichment with 50 kg $ZnSO_4$ ha-^{1}) and was on par with T_7 (RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)). The lowest zinc uptake was obtained with T_1 (RDF alone (Control) N: P_2O_5: K_2O - 200:60:50 kg ha-^{1}) treatment.

Higher zinc uptake in T_5 and T_7 was due to integrated application of enriched FYM, RDF and additive effect of the trace elements like foliar spray of Zn @ 0.2 % has increased timely and sufficient nutrient availability to the plants and absorption by maize leaves resulting in better absorption, assimilation and translocation of nutrients. Faujdar *et al.* (2014), Shivay and Prasad (2014), Kanwal *et al.* (2010) reported the similar results earlier.

CONCLUSION

Among the different application methods and sources of zinc tested, the treatment T_5 (RDF + FYM enrichment with 50 kg $ZnSO_4$ ha-1) recorded significantly higher nutrient uptake (N, P, K and Zn kg ha-^{1}) and it was on par with T_7 (RDF + ZSB (1kg/100 kg FYM) + 0.2% Foliar spray of $ZnSO_4$ (Knee-high and Tasseling stages)). It might be due to integrated application of chemical fertilizers, enriched FYM with ZSB or $ZnSO_4$ along with foliar spray @ 0.2 % $ZnSO_4$

DECLARATIONS

Conflict of interest: *The authors declare that they have no conflict of interest.*

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